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THE ART OF PAPER-MAKING

A PRACTICAL HANDBOOK OF THE MANUFACTURE OF PAPER FROM RAGS, ESPARTO, STRAW, AND OTHER FIBROUS MATERIALS, INCLUDING THE MANUFACTURE OF PULP FROM WOOD FIBRE

With a Description of the Machinery and Appliances used

TO WHICH ARE ADDED

DETAILS OF PROCESSES FOR RECOVERING SODA FROM WASTE LIQUORS

By ALEXANDER WATT
AUTHOR OF "THE ART OF SOAP-MAKING," "LEATHER MANUFACTURE," "ELECTRO METALLURGY," "ELECTRO-DEPOSITION," ETC., ETC.

LONDON
CROSBY LOCKWOOD AND SON
7, STATIONERS' HALL COURT, LUDGATE HILL
1890

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PREFACE.

In the present volume, while describing the various operations involved in the manufacture of paper, the Author has endeavoured to render the work serviceable as a book of reference in respect to the processes and improvements which have from time to time been introduced, and many of which have been more or less practically applied either at home or abroad.

The recovery of soda from waste liquors has been fully dealt with, and the details of several applied processes explained.

Special attention has also been directed to some of the more important methods of producing pulp from wood fibre, since it is highly probable that from this inexhaustible source the paper-maker will ultimately derive much of the cellulose used in his manufacture. Indeed it may be deemed equally probable, when the processes for disintegrating wood fibre, so largely applied in America and on the Continent, become better understood in this country, that their adoption here will become more extensive than has hitherto been the case.

To render the work more readily understood alike by the practical operator and the student, care has been taken to avoid, as far as possible, the introduction of unexplained technicalities; at the same time it has been the writer's aim to furnish the reader with a variety of information which, it is hoped, will prove both useful and instructive.

It is with much pleasure that the Author tenders his sincere thanks to Mr. Sydney Spalding, of the Horton Kirby Mills, South Darenth, for his kind courtesy in conducting him through the various departments of the mill, and for explaining to him the operations performed therein. To Mr. Frank Lloyd he also acknowledges his indebtedness for the generous readiness with which he accompanied him over the *Daily Chronicle* Mill at Sittingbourne, and for the pains he took to supply information as to certain details at the Author's request. His best thanks are also due to those manufacturers of paper-making machinery who supplied him with many of the blocks which illustrate the pages of the book.

BALHAM, SURREY, *January*, 1890.

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THE ART

OF

PAPER-MAKING.

CHAPTER I.

CELLULOSE.

Cellulose.—Action of Acids on Cellulose.—Physical Characteristics of Cellulose.—Micrographic Examination of Vegetable Fibres.—Determination of Cellulose.—Recognition of Vegetable Fibres by the Microscope.

Cellulose.—Vegetable fibre, when deprived of all incrusting or cementing matters of a resinous or gummy nature, presents to us the true fibre, or *cellulose*, which constitutes the essential basis of all manufactured paper. Fine linen and cotton are almost pure cellulose, from the fact that the associated vegetable substances have been removed by the treatment the fibres were subjected to in the process of their manufacture; pure white, unsized, and unloaded paper may also be considered as pure cellulose from the same cause. Viewed as a chemical substance, cellulose is white, translucent, and somewhat heavier than water. It is tasteless, inodorous, absolutely innutritious, and is insoluble in water, alcohol, and oils. Dilute acids and alkalies, even when hot, scarcely affect it. By prolonged boiling in dilute acids, however, cellulose undergoes a gradual change, being converted into *hydro-cellulose.* It is also affected by boiling water alone, especially under high pressure, if boiled for a lengthened period. Without going deeply into the chemical properties of cellulose, which would be more interesting to the chemist than to the paper manufacturer, a few data respecting the action of certain chemical substances upon cellulose will, it is hoped, be found useful from a practical point of view, especially at the present day, when so many new methods of treating vegetable fibres are being introduced.

Action of Acids on Cellulose.—When concentrated sulphuric acid is added very gradually to about half its weight of linen rags cut into small shreds, or strips of unsized paper, and contained in a glass vessel, with constant stirring, the fibres gradually swell up and disappear, without the evolution of any gas, and a tenacious mucilage is formed which is entirely soluble in water. If, after a few hours, the mixture be diluted with water, the acid neutralised with chalk, and after filtration, any excess of lime thrown down by cautiously adding a solution of oxalic acid, the liquid yields, after a second filtration and the addition of alcohol in considerable excess, a gummy mass which possesses all the characters of *dextrin*. If instead of at once saturating the diluted acid with chalk, we boil it for four or five hours, the dextrin is entirely converted into grape sugar (*glucose*), which, by the addition of chalk and filtration, as before, and evaporation at a gentle heat to the consistence of a syrup, will, after repose for a few days, furnish a concrete mass of crystallised sugar. Cotton, linen, or unsized paper, thus treated, yield fully their own weight of gum and one-sixth of their weight of grape sugar. Pure cellulose is readily attacked by, and soon becomes dissolved in, a solution of oxide of copper in ammonia (*cuprammonium*), and may again be precipitated in colourless flakes by the addition of an excess of hydrochloric acid, and afterwards filtering and washing the precipitate. Concentrated boiling hydrochloric acid converts cellulose into a fine powder, without, however, altering its composition, while strong nitric acid forms nitro-substitution products of various degrees, according to the strength of the acid employed. "Chlorine gas passed into water in which cellulose is suspended rapidly oxidises and destroys it, and the same effect takes place when hypochlorites, such as hypochlorite of calcium, or bleaching liquors, are gently treated with it. It is not, therefore, the cellulose itself which we want the bleaching liquor to operate upon, but only the colouring matters associated with it, and care must be taken to secure that the action intended for the extraneous substances alone does not extend to the fibre itself. Caustic potash affects but slightly cellulose in the form in which we have to do it, but in certain less compact conditions these agents decompose or destroy it."—*Arnot.*[*]

Physical Characteristics of Cellulose.—"The physical condition of cellulose," says Mr. Arnot, "after it has been freed from extraneous matters by boiling, bleaching, and washing, is of great importance to the manufacturer. Some fibres are short, hard, and of polished exterior, while others are long, flexible, and barbed, the former, it is scarcely necessary to say, yielding but indifferent papers, easily broken and torn, while the papers produced from the latter class of fibres are possessed of a great degree of strength and flexibility. Fibres from straw, and from many varieties of wood, may be taken as representatives of the former class, those from hemp and flax affording good illustrations of the latter. There are, of course, between these extremes all degrees and combinations of the various characteristics indicated. It will be readily understood that hard, acicular[†] fibres do not felt well, there being no intertwining or adhesion of the various particles, and the paper produced is friable. On the other hand, long, flexible, elastic fibres, even though comparatively smooth in their exterior, intertwine readily, and felt into a strong tough sheet. . . . . Cotton fibre is long and tubular, and has this peculiarity, that when dry the tubes collapse and twist on their axes, this property greatly assisting the adhesion of the particles in the process of paper-making. In the process of dyeing cotton, the colouring matter is absorbed into the tubes, and is, as will be readily appreciated, difficult of removal therefrom. Papers made exclusively of cotton fibre are strong and flexible, but have a certain sponginess about them which papers made from linen do not possess."

---

[*] Cantor Lectures, *Journal of Society of Arts*, vol. xxvi. p. 74.

[†] Needle-shaped, slender and sharp-pointed.

Linen—the cellulose of the flax-plant—before it reaches the hands of the paper-maker has been subjected to certain processes of steeping or *retting*, and also subsequent boilings and bleachings, by which the extraneous matters have been removed, and it therefore requires but little chemical treatment at his hands. "Linen fibre," Arnot further observes, "is like cotton, tubular, but the walls of the tubes are somewhat thicker, and are jointed or notched like a cane or rush; the notches assist greatly in the adhesion of the fibres one to another. This fibre possesses the other valuable properties of length, strength, and flexibility, and the latter property is increased when the walls of the tubes are crushed together under the action of the beating-engine." From this fibre a very strong, compactly felted paper is made; indeed, no better material than this can be had for the production of a first-class paper. Ropes, coarse bags, and suchlike are made from hemp, the cellulose or fibre of which is not unlike that of flax, only it is of a stronger, coarser nature. Manilla * yields the strongest of all fibres. Jute, which is the fibre or inside bark of an Indian plant (*Corchorus capsularis*), yields a strong fibre, but is very difficult to bleach white. Esparto fibre holds an intermediate place between the fibres just described and those of wood and straw. . . . The fibre of straw is short, pointed, and polished, and cannot of itself make a strong paper. The nature of wood fibre depends, as may readily be supposed, upon the nature of the wood itself. Yellow pine, for example, yields a fibre long, soft, and flexible, in fact very like cotton; while oak and many other woods yield short circular fibres which, unless perfectly free from extraneous matters, possess no flexibility, and in any case are not elastic.

---

* Manilla hemp.

Micrographic Examination of Vegetable Fibres.—The importance of the microscope in the examination of the various fibres that are employed in paper manufacture will be readily evident from the delicate nature of the cellulose to be obtained therefrom.* Amongst others M. Girard has determined, by this method of examination, the qualities which fibres ought to possess to suit the requirements of the manufacturer. He states that absolute length is not of much importance, but that the fibre should be slender and elastic, and possess the property of turning upon itself with facility. Tenacity is of but secondary importance, for when paper is torn the fibres scarcely ever break. The principal fibres employed in paper-making are divided into the following classes:—

1. *Round, ribbed fibres*, as hemp and flax.
2. *Smooth*, or *feebly-ribbed fibres*, as esparto, jute, phormium (New Zealand flax), dwarf palm, hop, and sugar-cane.
3. *Fibro-cellular substances*, as the pulp obtained from the straw of wheat and rye by the action of caustic ley.
4. *Flat fibres*, as cotton, and those obtained by the action of caustic ley upon wood.
5. *Imperfect substances*, as the pulp obtained from sawdust. In this class may also be included the fibre of the so-called "mechanical wood pulp."

Determination of Cellulose. For the determination of cellulose in wood and other vegetable fibres to be used in paper-making Müller recommends the following processes: † 5 grammes weight of the finely-divided substance is boiled four or five times in water, using 100 cubic centimètres ‡ each time. The residue is then dried at 100° C. (212° Fahr.), weighed, and exhausted with a mixture of equal measures of benzine and strong alcohol, to remove fat, wax, resin, &c. The residue is again dried and boiled several times in water, to every 100 c.c. of which 1 c.c. of strong ammonia has been added. This treatment removes colouring matter and pectous* substances. The residue is further bruised in a mortar if necessary, and is then treated in a closed bottle with 250 c.c. of water, and 20 c.c. of bromine water containing 4 c.c. of bromine to the litre.† In the case of the purer bark-fibres, such as flax and hemp, the yellow colour of the liquid only slowly disappears, but with straw and woods decolorisation occurs in a few minutes, and when this takes place more bromine water is added, this being repeated until the yellow colour remains, and bromine can be detected in the liquid after twelve hours. The liquid is then filtered, and the residue washed with water and heated to boiling with a litre of water containing 5 c.c. of strong ammonia. The liquid and tissue are usually coloured brown by this treatment. The undissolved matter is filtered off, washed, and again treated with bromine water. When the action seems complete the residue is again heated with ammoniacal water. This second treatment is sufficient with the purer fibres, but the operation must be repeated as often as the residue imparts a brownish tint to the alkaline liquid. The cellulose is thus obtained as a pure white body; it is washed with water, and then with boiling alcohol, after which it may be dried at 100° C. (212° Fahr.) and weighed.

---

* For this purpose, a microscope having a magnifying power of 120 to 150 diameters will be found efficient.

† "Commercial Organic Analysis." By A. H. Allen, F.C.S., vol. i. p. 316.

‡ For Table of French Measures see end of this work.

Recognition of Vegetable Fibres by the Microscope.— From Mr. Allen's admirable and useful work on "Commercial Organic Analysis"‡ we make the following extracts, but must refer the reader to the work named for fuller information upon this important consideration of the subject. In examining fibres under the microscope, it is recommended that the tissues should be cut up with sharp scissors, placed on a glass slide, moistened with water, and covered with a piece of thin glass. Under these conditions :—

---

* *Pectous*, pertaining to or consisting of *pectose* or *pectin*. Pectose is a substance contained in the pulp of unripe fleshy fruit, also in fleshy roots and other vegetable organs. It is insoluble in water, but under the influence of acids is transformed into *pectin*.

† A *litre* equals 34 fluid ounces *nearly*.

‡ "Commercial Organic Analysis." By A. H. Allen, F.C.S., vol. i.

Filaments of Cotton appear as transparent tubes, flattened and twisted round their axes, and tapering off to a closed point at each end. A section of the filament somewhat resembles the figure 8, the tube, originally cylindrical, having collapsed most in the middle, forming semi tubes on each side, which give the fibre, when viewed in certain lights, the appearance of a flat ribbon, with the hem of the border at each edge. The twisted, or corkscrew form of the dried filament of cotton distinguishes it from all other vegetable fibres, and is characteristic of the matured pod, M. Bauer having found that the fibres of the unripe seed are simply untwisted cylindrical tubes, which never twist afterwards if separated from the plant. The matured fibres always collapse in the middle as described, and undergo no change in this respect when passing through all the various operations to which cotton is subject, from spinning to its conversion into pulp for paper-making.

Linen, or Flax Fibre, under the microscope, appears as hollow tubes, open at both ends, the fibres being smooth, and the inner tube very narrow, and joints, or *septa*,* appear at intervals, but are not furnished with hairy appendages as is the case with hemp. When flax fibre is immersed in a boiling solution of equal parts of caustic potash and water for about a minute, then removed and pressed between folds of filter-paper, it assumes a dark yellow colour, whilst cotton under the same treatment remains white or becomes very bright yellow. When flax, or a tissue made from it, is immersed in oil, and then well pressed to remove excess of the liquid, it remains translucent, while cotton, under the same conditions, becomes opaque.

---

* *Septa*, plural of *septum*, a partition, as the partitions of an orange, for example.

New Zealand Flax (*Phormium tenax*) may be distinguished from ordinary flax or hemp by a reddish colour produced on immersing it first in a strong chlorine water, and then in ammonia. In machine-dressed New Zealand flax the bundles are translucent and irregularly covered with tissue; spiral fibres can be detected in the bundles, but less numerous than in Sizal. In Maori-prepared phormium the bundles are almost wholly free from tissue, while there are no spiral fibres.

Hemp Fibre resembles flax, and exhibits small hairy appendages at the joints. In Manilla hemp the bundles are oval, nearly opaque, and surrounded by a considerable quantity of dried-up cellular tissue composed of rectangular cells. The bundles are smooth, very few detached ultimate fibres are seen, and no spiral tissue.

Sizal, or Sisal Hemp (*Agave Americana*), forms oval fibrous bundles surrounded by cellular tissue, a few smooth ultimate fibres projecting from the bundles; is more translucent than Manilla, and a large quantity of spiral fibres are mixed up in the bundles.

Jute Fibre appears under the microscope as bundles of tendrils, each being a cylinder, with irregular thickened walls. The bundles offer a smooth cylindrical surface, to which the silky lustre of jute is due, and which is much increased by bleaching. By the action of hypochlorite of soda the bundles of fibres can be disintegrated, so that the single fibres can be readily distinguished under the microscope. Jute is coloured a deeper yellow by sulphate of aniline than is any other fibre.

CHAPTER II.

MATERIALS USED IN PAPER-MAKING.

Raw Materials.—Rags.—Disinfecting Machine.—Straw.—Esparto Grass.—Wood.—Bamboo.—Paper Mulberry.

In former days the only materials employed for the manufacture of paper were linen and cotton rags, flax and hemp waste, and some few other fibre-yielding materials. The reduction of the excise duty, however, from 3d. to 1½d. per lb., which took effect in the first year of Her Majesty's reign—namely, in 1837—created a greatly increased demand for paper, and caused much anxiety amongst manufacturers lest the supply of rags should prove inadequate to their requirements. Again, in the year 1861 the excise duty was totally abolished, from which period an enormously increased demand for paper, and consequently paper material, was created by the establishment of a vast number of daily and weekly papers and journals in all parts of the kingdom, besides reprints of standard and other works in a cheap form, the copyright of which had expired. It is not too much to say, that unless other materials than those employed before the repeal of the paper duty had been discovered, the abolition of the impost would have proved but of little service to the public at large. Beneficent Nature, however, has gradually, but surely and amply, supplied our needs through the instrumentality of man's restless activity and perseverance.

The following list comprises many of the substances from which cellulose, or vegetable fibre, can be separated for the purposes of paper-making with advantage; but the vegetable kingdom furnishes in addition a vast number of plants and vegetables which may also be used with the same object. We have seen voluminous lists of fibre-yielding materials which have been suggested as suitable for paper-making, but since the greater portion of them are never likely to be applied to such a purpose, we consider the time wasted in proposing them. It is true that the stalks of the cabbage tribe, for example, would be available for the sake of their fibre, but we should imagine that no grower of ordinary intelligence would deprive his ground of the nourishment such waste is capable of *returning to the soil,* by its employment as manure, to furnish a material for paper-making. Again, we have seen blackberries, and even the pollen (!) of plants included in a list of paper materials, but fortunately the manufacturer is never likely to be reduced to such extremities as to be compelled to use materials of this nature.

Raw Materials.

Cotton rags.
Cotton wool.
Cotton waste.
Cotton-seed waste.
Linen rags.
Linen waste.
Hemp waste.
Manilla hemp.
Flax waste, etc.
Jute waste, etc.
China grass.
Bamboo cane.
Rattan cane.
Banana fibre.
Straw of wheat, etc.
Rushes of various kinds.
New Zealand flax.
Maize stems, husks, etc.
Esparto grass.
Reeds.
Woods of various kinds, especially white non-resinous woods, as poplar, willow, etc.
Wood shavings, sawdust, and chips.
Barks of various trees, especially of the paper mulberry.
Peat.
Twigs of common broom and heather.
Mustard stems after threshing.
Buckwheat straw.
Tobacco stalks.
Beetroot refuse from sugar works.
Megass, or "cane trash"—refuse of the sugar cane after the juice has been extracted.
Fern leaves.
Tan waste.
Dyers' wood waste.
Old bagging.
Old bast matting.
Hop-bines.
Bean-stalks.
Old canvas.
Old rope.
Gunny bags.
Waste paper.
Binders' clippings, etc.

Old netting.
Sailcloth.
Sea grass (*Zostera marina*).
Fibrous waste resulting from pharmaceutical preparations.
Potato stalks.
Stable manure.
Silk cocoon waste.
Oakum.
Flax tow.
Rag bagging.
Leather waste.
Tarpaulin.
Etc., etc.

Rags.—Linen and cotton rags are imported into Great Britain from almost all the countries of Europe, and even from the distant states of South America, British South Africa, and Australasia. The greater proportion, however, come from Germany. The rags collected in England chiefly pass through the hands of wholesale merchants established in London, Liverpool, Manchester, and Bristol, and these are sorted to a certain extent before they are sent to the paper-mills. By this rough sorting, which does not include either cleansing or disinfecting, certain kinds of rags which would be useless to the paper-maker are separated and sold as manure. Woollen rags are not usually mixed with cotton rags, but are generally kept apart to be converted into "shoddy." The importance of disinfecting rags before they pass through the hands of the workpeople employed at the paper-mills cannot be over-estimated, and it is the duty of every Government to see that this is effectually carried out, not only at such times when cholera and other epidemics are known to be rife in certain countries from which rags may be imported, but at all times, since there is no greater source of danger to the health of communities than in the diffusion of old linen and cotton garments, or pieces, which are largely contributed by the dwellers in the slums of crowded cities.

Respecting the disinfecting of rags, Davis* thus explains the precautions taken in the United States to guard against the dangers of infection from rags coming from foreign or other sources. "When cholera, or other infectious or contagious diseases exist in foreign countries, or in portions of the United States, the health officers in charge of the various quarantines in this country require that rags from countries and districts in which such diseases are prevalent shall be thoroughly disinfected before they are allowed to pass their stations. Rags shipped to London, Hull, Liverpool, Italian, or other ports, and re-shipped from such ports to the United States, are usually subjected to the same rule as if shipped direct from the ports of the country in which such diseases prevail. It is usually requisite that the disinfection shall be made at the storehouse in the port of shipment, by boiling the rags several hours under a proper degree of pressure, or in a tightly-closed vessel, or disinfected with sulphurous acid, which is evolved by burning at least two pounds of roll sulphur to every ten cubic feet of room space, the apartment being kept closed for several hours after the rags are thus treated. Disinfection by boiling the rags is usually considered to be the best method. In the case of rags imported from India, Egypt, Spain, and other foreign countries where cholera is liable to become epidemic, it is especially desirable that some efficient, rapid, and thorough process of disinfecting should be devised. In order to meet the quarantine requirements, it must be thorough and certain in its action, and in order that the lives of the workmen and of others in the vicinity may not be endangered by the liberating of active disease-germs, or exposure of decaying and deleterious matters, and that the delay, trouble, and exposure of unbaling and rebaling may be avoided, it must be capable of use upon the rags while in the bale, and of doing its work rapidly when so used."

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* "Manufacture of Paper." By C. T. Davis, Philadelphia, 1887.

Disinfecting Machine.—To facilitate the disinfecting of rags while in the bale, Messrs. Parker and Blackman devised a machine, for which they obtained a patent in 1884, from which the following abstract is taken.

Formerly rags and other fibrous materials were disinfected by being subjected to germ-destroying gases or liquids in enclosed chambers, but in order to render the disinfecting process effectual, it was found necessary to treat the material in a loose or separated state, no successful method having been adopted for disinfecting the materials while in the bale. “This unbaling and loosening or spreading of the undisinfected material is absolutely unsafe and dangerous to the workmen, or to those in the vicinity, because of the consequent setting free of the disease germs, and the exposing of any decaying or deleterious matters which may be held in the material while it is compressed in the bale. The unbaling and necessary rebaling of the material for transportation also involves much trouble and expense and loss of time. Large and cumbrous apparatus is also necessary to treat large quantities of material loosened or opened out as heretofore.”

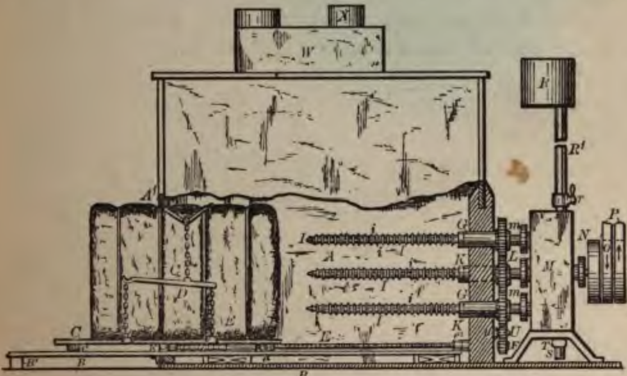

Fig. 1.

It is specially necessary that rags coming from Egypt and other foreign countries should be thoroughly disinfected by some rapid and effectual means, which, while not endangering the health of workmen employed in this somewhat hazardous task, will fully meet all quarantine requirements. The apparatus devised by Messrs. Parker and Blackman,* an abridged description of which is given below, will probably accomplish this much-desired object.

* Patent dated 16th December, 1884, No. 539.

X^1, forming a continuation of the opening; by this means all foul and deleterious vapours or gases passing out of the closed chamber A through the passage W must pass through the disinfecting liquid in the tank before escaping through the opening X and stack X^1 into the air, and are thus rendered harmless.

When a sufficient amount of the disinfectant has been forced into and through the bale, the disinfectant is turned off, and cold dry air can be forced through chamber M, and out through the nozzles and bale, whereby the material within the bale becomes cooled and dried, and all the foul air from the chamber A driven out, so that it may be opened and entered with safety. Any suitable disinfectant may be used with this apparatus, as, for example, sulphurous acid, in gas or solution, superheated steam, carbolic acid, or any solution or vapour containing chlorine.

Straw.—Very large quantities of this material are used in the manufacture of paper, but more especially for newspapers, the straw from wheat and oats being mostly employed. Although the percentage of cellulose in straw is about equal to that of esparto, the severe treatment it requires to effectually remove the silicious coating by which the fibre is protected, and to render the knots amenable to the action of the bleach, greatly reduces the yield of finished pulp. Many processes have been introduced for the treatment of straw for paper-making, but the most successful of them appear to be modifications of a process introduced in 1853 by MM. Coupier and Mellier.

Esparto Grass.—This important fibrous material is largely imported from Algeria, Spain, and other countries, and constitutes one of the most valuable fibre-yielding materials with which the manufacturer has to deal. Some idea of the amount of esparto and other fibres which find their way to our shores may be gleaned from the fact that while the import of cotton and linen rags in the year 1884 was 36,233 tons, of the value of £487,866, that of esparto and other fibres amounted to 184,005 tons, of the value of £1,125,553.

Wood.—As a paper-making material, the fibre obtained from various kinds of wood now holds an important position, since the sources of supply are practically inexhaustible. The first practical process for manufacturing pulp from wood fibre was perfected and introduced by the author's father, the late Mr. Charles Watt, who, in conjunction with Mr. H. Burgess, obtained a patent for the invention on August 19th, 1853. The process was afterwards publicly exhibited at a small works on the Regent's Canal, when the Earl of Derby (then Lord Stanley), many scientific men and representatives of the press, were present, and expressed themselves well satisfied with its success. Specimens of the wood paper, including a copy of the *Weekly Times* printed thereon, were exhibited, as also some water-colour drawings which had been produced upon paper made from wood pulp. Failing to get the process taken up in England, an American patent was applied for and obtained in 1854, which was subsequently purchased; but with the exception of an instalment, the purchase-money was never paid to the inventor! Thus the process "got" into other hands, the original inventor alone being unbenefited by it.

It has been repeatedly stated,* no doubt unwittingly, that a person named Houghton first introduced the wood paper process into this country; but considering that his patent was not obtained until 1857, or four years after the process above referred to was patented and publicly exhibited in England, it will be seen that the statement is absolutely without foundation. The first knowledge Mr. Houghton received concerning wood as a paper-making material was from the author's father, and he (Mr. Houghton), in conjunction with Mr. Burgess, introduced the Watt and Burgess process into America in the year 1854. These are the facts.

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* "Forestry and Forest Products," p. 501, and Cross and Bevan's "Text Book of Paper-making," p. 65.

Bamboo (*Bambusa vulgaris*).—The leaves and fresh-cut stems of this plant are used for paper material, but require to pass through a preliminary process of crushing, which is effected by suitable rolls, the second series of crushing rolls being grooved or channelled to split or divide the material, after which the stems are cut to suitable lengths for boiling.

Paper Mulberry (*Broussonetia papyrifera*).—The inner bark of this tree, and also some other basts, have long been used by the Japanese and Chinese in the manufacture of paper of great strength, but of extreme delicacy.

CHAPTER III.

TREATMENT OF RAGS.

Preliminary Operations.—Sorting.—Cutting.—Bertrams' Rag-cutting Machine.—Nuttall's Rag-cutter.—Willowing.—Bertrams' Willow and Duster.—Dusting.—Bryan Donkin's Duster or Willow.—Donkin's "Devil."

Preliminary Operations.—Before the rags are submitted to the various processes which constitute the art of paper-making, they are subjected to certain preliminary operations to free them from dirty matters, dust, and even sand, which is sometimes fraudulently introduced into rags to increase their weight. This preliminary treatment may be classified under the following heads, namely :—Sorting ; Cutting ; Willowing ; Dusting.

Sorting.—The rags being removed from the bags or bales in which they are packed, require first to be sorted according to the nature and quality of the fabrics of which they are composed ; thus linen, cotton, hemp, wool, &c., must be carefully separated from each other ; the thickness of the substance, its condition as to the wear it has undergone, and the colour of the material, all these considerations are taken into account by the women and girls who are employed in the operation of sorting. The finer qualities are set aside for writing-paper, inferior sorts being used separately, or mixed, according to the requirements of the manufacturer. Blue rags are generally separated from the rest and kept for the manufacture of blue paper, but most of the other coloured rags require bleaching. In sorting rags, a good deal of judgment and skill are required to avoid mixing the better qualities with those of an inferior class, which would occasion loss in the manufacture. It is also important that those of inferior colour should not be mixed with the finer qualities, which would be liable to affect the colour and deteriorate the quality of the paper. Paper manufacturers generally classify the rags obtained from home sources, that is, from different parts of the United Kingdom, under the following heads :—

Home Rags.

- New cuttings.
- Linen pieces.
- Cotton pieces.
- Fines (whites).
- Superfines (whites).
- Outshots (whites).
- Seconds (whites).
- Thirds (whites).
- Colours or prints.
- Blues.
- Gunny, clean.
- Gunny, dirty.
- Rope (white).
- Rope (hard).
- Rope, bagging, etc.

Foreign rags are distinguished as below :—

Belgian Rags.

- White linens.
- Mixed fines (linens and cottons).
- Grey linens.
- Strong linens.
- Extra fine linens
- Blue linens.
- Superfine white cottons.
- Outshot cottons.
- Seconds.
- Half jute and linen.
- Light prints.
- Mixed prints.
- Blue cottons.
- Fustians.
- Black calicoes.
- White hemp, strings, and rope.
- Tarred hemp, strings, and rope.
- Jute spinners' waste.
- Jute waste.

New.

- White linens.
- Grey linens.
- Blue linens.
- Unbleached cottons.
- White linens and cottons.
- Print cuttings (free from black).
- Blacks.
- Fustians.

French Rags.

- French linens.
- White cotton.
- Knitted cotton.
- Blue cotton.
- Coloured cotton.
- Black cotton.
- Marseilles whites.
- Light prints.
- Mixed prints.
- New white cuttings.

GERMAN RAGS.

S. P. F. F. F.
S. P. F.
F. F.
F. G.
L. X. F.

L. F. B. blue.
C. S. P. F. F. F.
O. F. B. blue.
C. F. X. coloured.

TRIESTE.

P. P. white linen (first).
P. white linen (second).

S. fine greys.
X. coloured cottons.

LEGHORN.

P. L. linens.
P. C. cottons.

S. C.
T. C.

TURKEY AND BEYROUT.

Bright reds.

ALEXANDRIA.

Whites.
Blues.
Colours.

BALTIC AND RUSSIAN.

S. P. F. F.
S. P. F.
L. F. B.
F. G.

F. F.
B. G.
L. F. X.

Woollen rags are only used to a very moderate extent in blotting and filtering papers and also in coarse papers and wrappers. Many attempts have been made to bleach woollen rags, but the severity of the treatment required invariably ended in a destruction of the fibrous substances mingled with them. It is customary to dispose of such material for re-making into common cloths; and for shoddy. Rags collected in large cities, in consequence of the frequent bleachings they have been subjected to, are considerably weakened in fibre, tearing easily, and are therefore subject to loss in process of manufacture into pulp. Country rags, being coarser and greyer because less bleached, are stronger in fibre and give a better body to the paper. In sampling rags it is necessary to take precautions against the fraudulent "tricks of the trade," which are often resorted to to cheat the manufacturer. Samples should be taken from the interior of the bags or bales, to ascertain if the material in the interior is equal in quality with that at the outside—that is to say, that the quality is fairly averaged throughout. It may also be found that the rags have been purposely wetted to increase their weight. If such is found to be the case, a few handfuls should be weighed, and then dried in a warm room, and afterwards re-weighed, when if the loss exceeds 5 to 7 per cent. it may be assumed that the rags have been fraudulently wetted. It is generally found, however, that the merchants in the principal towns transact their business honourably and are therefore reliable.

The sorting is generally performed by women, who not only separate the various qualities of the rags, which they place in separate receptacles, but also remove all buttons, hooks and eyes, india-rubber, pins and needles, &c., and loosen all seams, hems and knots. The rags are next carefully looked over by women called *overhaulers*, or over-lookers, whose duty it is to see that the previous operations have been fully carried out in all respects. Usually there is one over-hauler to every eight or ten *cutters*.

Cutting.—In some mills it is preferred to have the rags cut into pieces from 2 to 4 inches square, but the actual size is not considered of much importance. The chief object is to have them in such a condition that they may be thoroughly cleansed in subsequent operations, and able to float throughout the water in the rag-engine, without twisting round the roller. If the rag pieces are smaller than is required to effect this it tends to create a loss of fibre in the operations of willowing and dusting.

The process of cutting is performed by hand or by machinery. When the rags are cut by hand, the operation, which is accomplished by women, is conducted as follows:—The cutter takes her place in front of an oblong box, as in Fig. 3, covered with coarse wire netting, containing three threads per inch, through which dust, &c., passes to a receptacle beneath; in the centre is fixed, in a slanting position, a large-bladed knife of peculiar form, with its back towards the operator, who is surrounded by a number of boxes, corresponding with the number of the different qualities of rags; these are lined at the bottom with coarse wire gauze. In the operation of cutting, if any foreign substances, such as buttons, hooks, &c., which may have escaped the sorters are found, these are at once removed. The rags as they are cut are put into baskets to be conveyed to the rag-engine room. In some mills rags are cut by machinery, but hand cutting is usually adopted for the better kinds of paper, as it is obvious that the machine would not be able to reject, as is the case in hand cutting, unpicked seams and other irregularities which may have escaped observation by the sorters and overhaulers. Machine cutting is, therefore, generally adopted for the materials which are to be used for the coarser papers. There are several rag-cutting machines in use, of which one or two examples are given below.

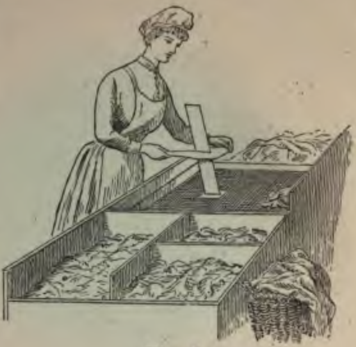

Fig. 3.

Bertrams' Rag-Cutting Machine.—The engraving, Fig. 4, represents a machine manufactured by Messrs. Bertrams, Limited, of St. Katherine's Works, Edinburgh, to whose courtesy we are indebted for this and other illustrations of their machinery, which have been reproduced in outline from their illustrated catalogue. The machine, which is suitable either for rags or ropes, has three revolving knives, and one dead knife, which is rendered reversible to four edges, and has self-acting feed gear, side frames, drum, and other connections of substantial construction; it is wood covered, and furnished with sheet-iron delivery spout. The material passes into the machine along the table at *a*, where it passes between the dead knife *c* and the knives *b* fixed to the revolving drum *d*. The cut rags fall into a receptacle beneath the drum.

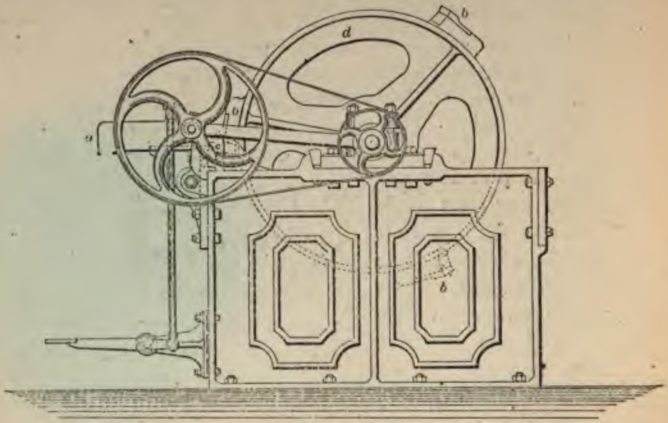

Fig. 4.

Nuttall's Rag Cutter.—Another type of rag cutter, and which is also suitable for cutting bagging, sailcloth, tarpaulin, Manilla and other fibres, is Nuttall's Rag Cutter, a drawing of which is shown in Fig. 5. This machine is manufactured by Messrs. Bentley and Jackson, of Bury, near Manchester, and is generally known as the "Guillotine Rag Cutter," from the principle of its action, which is that of chopping the material. The machine is adopted at many mills, and a large-sized machine has recently been put down at the *Daily Telegraph* mills, Dartford. A medium-sized machine will cut about one ton of rags in an hour.

Willowing.—In some mills the cut rags are conveyed to a machine called the "willow," which in one form of machine consists of two cast-iron cylinders, 2½ feet in diameter and 3½ feet wide, provided with numerous iron teeth, which project about 4 inches. These cylinders are placed one behind the other, and beneath them is a semicircular screw, and above them a cover of the same form. This cover is also furnished with teeth, and is so adjusted that the teeth in the cylinders pass those in the cover at a distance of ½ to ¾ of an inch. In front are a pair of rollers and revolving apron, which carry the rags into the cylinders, which rotate rapidly; and the rags, which are thrown by the first into the second cylinder, are allowed to remain in them for about 20 seconds, when a sliding door, which rises three times per minute, allows the rags to be discharged into a duster. Each time the sliding door opens the revolving apron moves forward and recharges the willow with a fresh supply. The rags, after being beaten and teazed in the willow, are considerably loosened in texture, and a good deal of dust and gritty matters fall through the screen beneath.

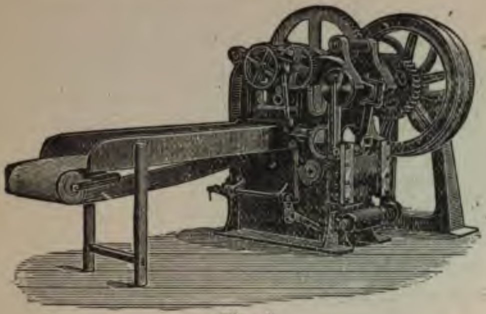

Fig. 5.

Fig. 6 represents a combined willow and duster, specially useful for waste rags and jute, but may be used for all fibres, manufactured by Bertrams, Limited, the main features of which are thus described:—"There are two drums, which have malleable-iron cross-bars and teeth, and malleable-iron harp motion below for escape of dust.

The framework of the willow is of cast iron, and the sides are filled in with cast-iron panel doors, the top being covered in with sheet iron. The gear is arranged so that the willow will deliver to the duster or otherwise by self-acting motion continuously or intermittently. The feed to the willow can also be made continuous or intermittent. The drums, framework, panels, and casing being made of iron, the chance of fire from the friction of its working is reduced to a minimum. The duster, as a rule, is 12 feet long, about 5 feet in diameter, and has eight longitudinal bars of cast iron fitted between the front and end revolving rings. These bars are fitted with malleable-iron spikes, pitched and so arranged that the rags or fibres are delivered at the exit end automatically. The outside of the duster can be lined with wire-cloth, perforated zinc, iron, etc. It is driven by outside shafts and friction gear, so that there is no internal shaft to interfere with the delivery of the fibres."

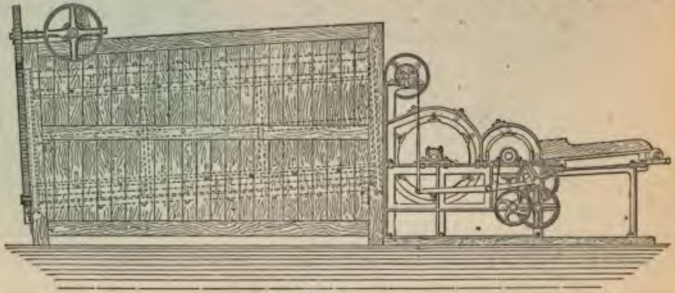

Fig. 6.

Dusting.—In Fig. 7 is shown a rag-dusting machine, manufactured by Messrs. Bryan Donkin and Co., of Bermondsey, London. The cylinder of this machine, which is conical in form, to enable the rags to travel from one end to the other, whence they are ejected, revolves, as also does a second cylinder of a skeleton form, but in the opposite direction. Each cylinder is fitted with knives, or spikes—those of the outer cylinder projecting towards the centre; the knives of the centre cylinder being attached to its exterior surface: when the machine is in motion the two sets of blades pass each other so that when the rags come between them the action is that of scissors. When the rags are ejected at the end of the cylinder, they pass into another cylinder of wire, through which the dust falls and leaves them in a fairly clean condition, when they are lowered through a trap-door to the boiling room below.

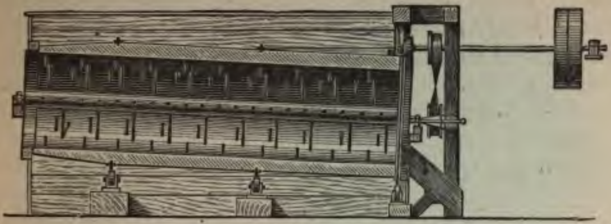

Fig. 7.

Donkin's "Devil."—For removing the dust and dirt from coarse and very dirty rags, oakum, rope, etc., the presence of which would seriously injure the quality of the paper, a still more powerful machine has been in-

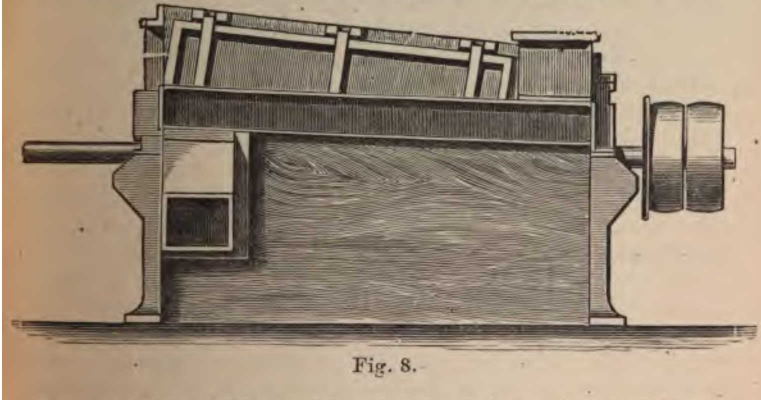

Fig. 8.

troduced, called the "devil," which is constructed on the same principle as the willow, but revolves at a lower speed. The revolving axle of this machine is conical, and is provided with teeth, arranged in a spiral form. The case in which it rotates is fed continuously, instead of intermittently; and although it facilitates the subsequent treatment of the fibre, it is said to be wasteful, while also consuming a considerable amount of power. A machine, or "devil," for cleaning rags or half stuff is manufactured by Messrs. Donkin and Co., a representation of which is shown in Fig. 8.

CHAPTER IV.

TREATMENT OF RAGS (*continued*).

Boiling Rags.—Bertrams' Rag Boiler.—Donkin's Rag Boiler.—Washing and Breaking.—Bertrams' Rag Engine.—Bentley and Jackson's Rag Engine.—Draining.—Torrance's Drainer.

Boiling Rags.—To remove greasy matters, and also to dissolve out the cementing substances from the stems of flax and shell of the cotton, the rags are next boiled in a solution of caustic soda, caustic lime, or a mixture of carbonate of soda and lime. The boiling has also the effect of loosening the dirt contained in the rags, whereby the colour of the material is greatly improved, while at the same time it is rendered more susceptible to the action of the bleaching agent. Strong linen rags will sometimes lose from one-third to one-fifth of their weight by the process of boiling. The vessels for boiling rags are of various construction, and have been the subject of numerous ingenious patents. These boilers are either cylindrical or spherical, and are also stationary or rotary—the latter form being devised for the purpose of keeping the caustic alkali solution freely diffused throughout the mass of fibre during the boiling.

Bertrams' Rag Boiler.—An illustration of a spherical boiler, as manufactured by Bertrams, Limited, of Edinburgh, is given in Fig. 9. The shell of this boiler is made from malleable iron, is 8 feet in diameter and 9 feet deep. The boiler is constructed on what is termed the "vomiting" principle, by which a free circulation of the alkaline liquor is constantly maintained. These boilers are made to withstand any pressure of steam, but the size given is usually worked at from 35 to 45 lbs. pressure, and carries about 30 cwt. of dry esparto.

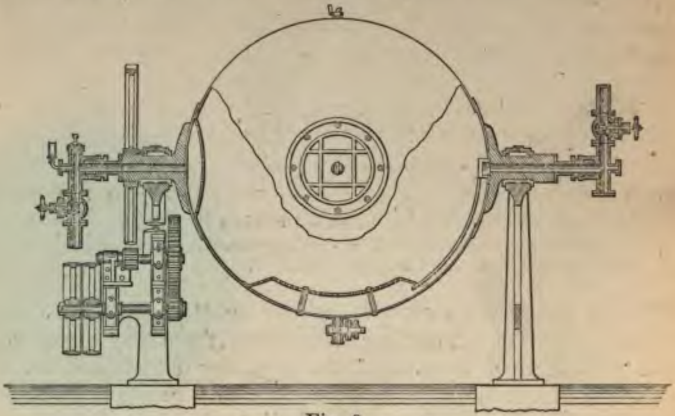

Fig. 9.

Donkin's Rag Boiler.—The spherical boiler of Messrs. Bryan Donkin and Co. is shown in Fig. 10. Being of a spherical form, it is twice as strong as a cylindrical boiler of the same diameter and thickness. The plates used are, notwithstanding, of the usual substance, thus rendering it perfectly safe, durable, and suitable for high-pressure steam. The spherical shape also allows the rags to fall out by themselves when the boiler is revolving with the cover off. Within the boiler are strainers to carry off the dirt, and lifters to agitate the rags during the process of either boiling or washing. To avoid cement, or even lead joints, the gudgeons and the boiler are turned true in the lathe to fit each other, the joints being simply made with red lead. These boilers are usually about 8 feet in diameter, and are capable of boiling from 20 cwt. to 25 cwt. of rags. The idea of giving motion to the boiler, so as to insure a perfect mixture of the rags and the caustic liquor, is of American origin, and was first introduced into this country by Messrs.

Bryan Donkin and Co. It is usual to fix the boiler so that it can be fed with rags through a trap in the floor above, while the boiler is in a vertical position and the lid removed. The trunnions are hollow, to admit the introduction of steam, alkaline ley, or water, and its rotary motion, which is about three times in two minutes, is given by the gearing on the left of the illustration.

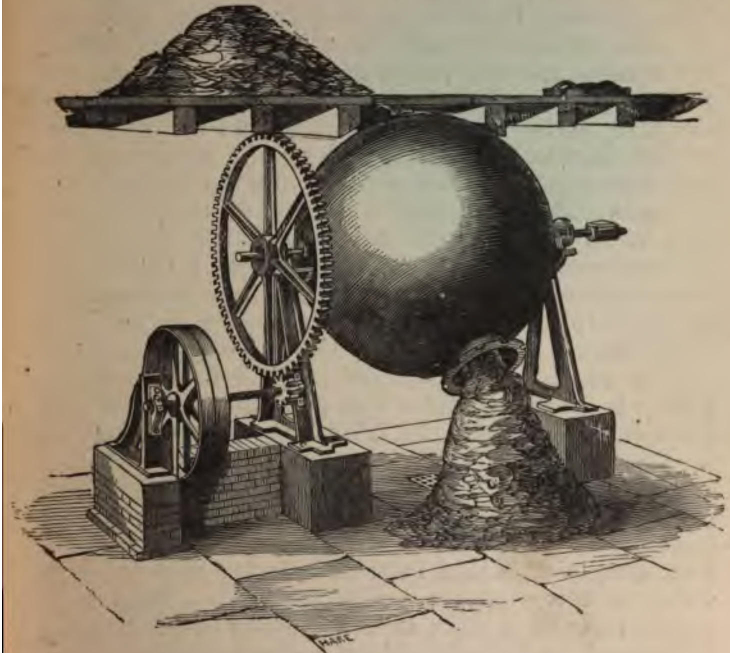

Fig. 10.

The alkalies used for boiling rags are either caustic soda, soda ash, slaked lime, made into a cream and sifted, or a mixture of slaked lime and carbonate of soda. A description of the preparation of caustic soda ley will be found in another chapter. It has been customary at most of the larger paper-mills to purchase their caustic soda direct from the alkali manufacturers, who supply it in a solid form enclosed in iron drums, hermetically closed, which are broken and the contents removed and dissolved when required for use. As to the strength of caustic soda liquor to be used for boiling rags, this is regulated according to the nature and condition of the material, and the quality of the paper it is intended for (see p. 34). For the finest papers the caustic soda should be perfectly pure, and as there are various grades of this chemical substance sold by the alkali makers, only the purer qualities are used for the better kinds of paper. The proportion of caustic soda per cwt. of rags varies to the extent of from 5 to 10 per cent. of the former to each cwt. of the latter, the coarser materials, of course, requiring more alkali than those of finer quality. In cases where rags are boiled in an open boiler—as was formerly the case—a much larger proportion of caustic soda would be required than when the boiling is conducted under high pressures, as is now very generally the custom. In boiling the finer qualities of rags, less pressure of steam is required than for the coarser qualities, and the heat being proportionately lower, there is less destruction of the fibre. Some paper-makers prefer to boil the rags with caustic lime only, in which case the lime, after being slaked in the usual way, is mixed with water until it attains a milky consistence, when it is passed through a sieve to separate any solid particles which may be present. About the same percentage of lime may be used as in the former case.

When a mixture of lime and carbonate of soda is used, a method much adopted on the Continent, the lime should be well screened from lumps before being mixed with the soda. The usual method of preparing this mixture is as follows :—A wooden tank, 15 feet long, 5 feet wide, and 4 feet deep is divided into three compartments, each of which has a false bottom perforated with ½-inch holes to keep back lumps, stones, pieces of coal, etc., which frequently abound in the lime. The fresh lime is put into the first compartment, where it is slaked with water in the usual way; the resulting powder is then put into the next compartment together with sufficient water, where it is agitated until converted into what is technically termed "milk of lime." In the partition which separates the second from the third division is a movable sluice, through which the milk of lime flows into the third compartment; in this is fitted a revolving drum, similar to the drum-washer of the breaking-engine, through which the milk of lime which flows from the sluice becomes strained, and is lifted in the same way as water is lifted by the drum-washer of the breaking-engine, and is thence discharged through a pipe into the rag boilers; an additional straining can be effected by placing a fine wire strainer over the mouth of this pipe leading to the boiler, which will prevent objectionable particles from entering the boiler. Each compartment is provided with a large waste pipe, through which, by the aid of a sufficient supply of water, all impurities which have been rejected by the drum are carried away. The soda solution is prepared by dissolving the required proportion in water, and the resulting liquor, after careful straining, is introduced into the boiler to which the charge of rags has been given; the head of the boiler is then fixed in its position and steam turned on, until a pressure of about 20 to 30 lbs. to the square inch is attained, and the boiling kept up for two to six hours, according to the quality of the rags. By the Continental system of boiling rags, for No. 1 stuffs, 216 lbs. of lime and 114 lbs., of 48 per cent., soda ash are used for every 4,000 lbs. of rags; for Nos. 3 and 5 stuffs, 324 lbs. of lime and 152 lbs. of soda ash are used; and for No. 4 stuff 378 lbs. of lime and 190 lbs. of soda ash, and the boiling in each case is kept up for twelve hours, under a pressure of 30 lbs., the operation being conducted in boilers which revolve horizontally.

In boiling the finest qualities of rags, it is considered preferable to boil with lime alone, which is believed to be less injurious to delicate fibres than caustic soda. Dunbar * gives the following proportions of 70 per cent. caustic soda per cwt. of rags :—

S. P. F. F. F. is boiled with lime alone, then washed in the boiler, and again boiled with 2 per cent. of soda ash.

S. P. F. F.	is boiled	with	12	lbs. of	(70 per cent.)	caustic soda	per cwt.
S. P. F	,,	,,	14	,,	,,	,,	,,
Fines	,,	,,	7	,,	,,	,,	,,
Seconds	,,	,,	6	,,	,,	,,	,,
L. F. X.	,,	,,	20	,,	,,	,,	,,
C. L. F. X.	,,	,,	27	,,	,,	,,	,,
C. C. L. F. X.	,,	,,	30	,,	,,	,,	,,
F. F.	,,	,,	15	,,	,,	,,	,,

These are all boiled at a pressure of from 20 to 25 lbs. for 10 hours, in stationary boilers without vomit, and also in boilers revolving horizontally. In some mills, where the best qualities of paper are made, iron boilers are objected to, as small particles of oxide of iron are apt to become dislodged from the interior of the boiler, and produce discolouration of the paper. In such cases wooden vats, with mechanical stirrers, are employed ; sometimes a jacketed boiler is used.

Washing and Breaking.—The removal of the dirty water resulting from the boiling is effected in the washing and breaking engine, or "rag engine," as it is commonly called, which is constructed on the same principle as the beating engine, but is provided with an extra drum, called the *drum-washer*, which, being covered with wire gauze, allows the washing waters to escape without permitting the fibrous stuff to pass through. The rag engine, having been invented by a Dutchman, acquired, and still retains, the name of the *Hollander*, and although it has been considerably improved upon, its principle is still retained in the modern engines, of which there are many different forms. The ordinary rag engine, Figs. 11 and 12, consists of a cast-iron trough A, about 10 feet long, 4½ feet wide, and 2½ feet deep, and rounded at the ends, and is firmly bolted to a wooden foundation. It is provided with a partition termed the *midfeather* B, of such a length as to have the trough of uniform width round it. A cylinder, or *roll*, C, furnished with a series of steel knives, rotates in one of the divisions formed by the midfeather, and the floor of the trough in this division is inclined in such a manner as to cause the pulp, as it travels, to pass under the roll. Beneath the roll is the *bed-plate*, which is fitted with a series of steel knives *c c* similar to those on the exterior of the roll. The distance between the knives of the roll and the bed-plate is regulated by levelling screws, which are so adjusted that both ends of the roll are raised at the same time, which is a great improvement upon the older types of breaking engines in which only one end of the roll was raised, whereby the knives became unequally worn. By

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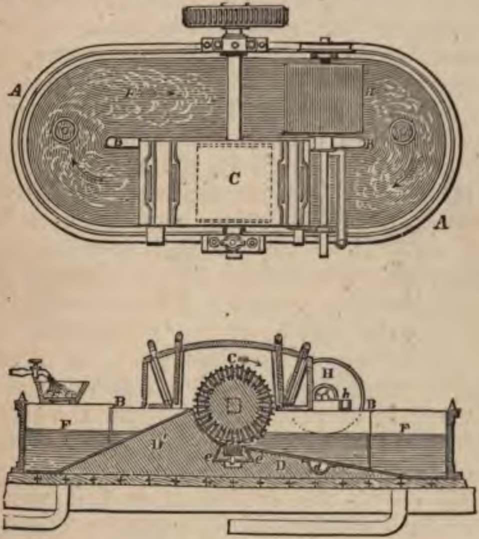
* "Practical Paper Maker," by James Dunbar. Mackenzie and Storrie, Leith, 1887.



Figs. 11 and 12.

the present method of regulating the distance between the respective sets of knives, any required degree of fineness can be given to the fibrous substances treated. The roll is generally caused to rotate at a speed of about 230 revolutions per minute, causing the water and rags to circulate in the engine and to be constantly under the action of the knives. In the other division F F of the trough is the drum-washer H, which, being covered with fine gauze wire, allows the water to enter, but keeps back the fibrous material. The ends of the drum are formed of two discs of wood, generally mahogany, upon which the coarse gauze is fastened as a backing, and this is covered with the fine wire gauze. The interior of the drum is sometimes furnished with a series of buckets, which conduct the water to a trough in the axis of the drum, by which it is led away. This is also accomplished by dividing the interior of the cylinder into compartments by means of a partition. The drum-washer is so arranged that it can be wholly raised out of the trough, which is necessary in certain parts of the operation, when the removal of the liquid is not required; or it can be partially raised, or otherwise, according to requirement. The floor of the compartment containing the roll C is inclined at D, so as to cause the pulp to pass directly under the roll, and at D′ is the *backfall*, over which the pulp travels to the opposite side of the midfeather.

In working the rag engine, it is first partly filled with water, and then set in motion; the boiled stuff is then gradually put in, and a constant supply of clean water is run in from a cistern provided with means of preventing sand or other impurities from finding their way into the engine. It is of the utmost importance that the water should be abundant and of good quality, more especially as the material (rags) is mostly required for making the finer qualities of paper. In this respect the county of Kent and a few other localities on the chalk formation are considered specially suitable for this particular manufacture.

With respect to the driving of the engines, this was formerly effected by what is called *toothed gearing*, but cog-wheels were afterwards replaced by iron spur-wheel gearing, which enabled manufacturers to drive four or more engines from one source of power, by continuing the line of shafting and spur-wheels; but even with small rolls the wear and tear on this system was considerable, while it was quite inadequate to the driving of a number of large rolls of 30 inches in diameter, such as are now used. The introduction of belt-gearing, by Messrs. G. and W. Bertram, proved to be a great improvement on the older system, and it is found that the rags are broken not only more uniformly, but in less time, as the rolls work more steadily on the plates than with any system of wheel-gearing, while the various working parts of the engine last longer than when subjected to the vibrating action of wheel-gearing.

Bertrams' Rag Engine.—This engine, of which a drawing is shown in Fig. 13, may be used either as a washing and breaking engine, potcher, or beater. It is provided with double lifting gear, and has "all sweeps, curves, and angles" of the most improved design to save

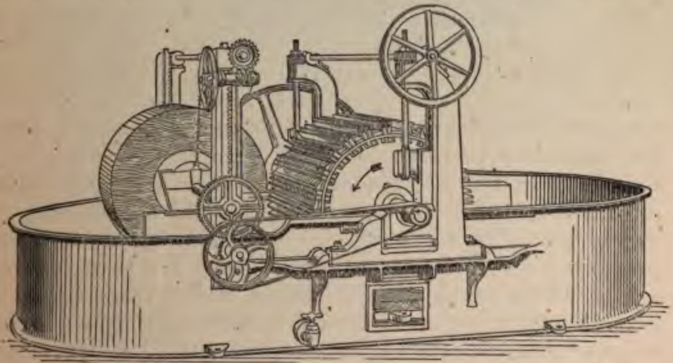


Fig. 13.

lodgments and ensure steady and thorough travelling of the pulp. The drum-washer is shown lifted by rack and pinion and worm gear, and empties down the midfeather direct to mouthpiece. The emptying can be done by spout and pipe, or by a chamber cast on the engine, down back or front side, as well as through the midfeather; but it is not advisable that it should be emptied down the midfeather if the rag engine is to be used as a beater.

Bentley and Jackson's Rag Engine.—This form of engine is shown in Fig. 14. The trough is of cast-iron, and made whole, and the engine can be obtained of any required dimensions. The trough is provided with a sand-well, cast-iron grate, and cock in front of the roll, and a sand-well, cast-iron grate, and brass valve on the back of the midfeather, a brass let-off valve and a brass waste-water valve. The bottom of the trough is "dished," to prevent the stuff from lodging. There are two movable bridge trees, fitted with pedestals and brass steps, and wrought-iron lifting links and screws, worm-wheels, worms, cross-shaft and hand-wheel for simultaneously lifting the roll on both sides. The roll is covered by a polished pitch-pine cover. The drum-washer may have either iron or wooden ends, has strong copper brackets, and is covered with brass backing and covering wires, mounted on a wrought-iron shaft, and carried by cast-

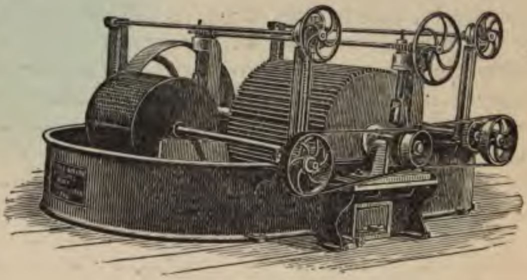


Fig. 14.

iron stands, fitted with improved lifting gear, driving-wheels, and pulley.

When the engine is set in motion by the revolving shaft or spindle, the combined action of the knives of the roll and bed-plate causes the rags, which circulate in the water, to be gradually cut into small fragments, and the operation is kept up until the rags are converted into what is technically termed *half-stuff*. While this process is going on, fresh water is constantly supplied by a pipe at the end of the washing-engine; and when it is found that nothing but clear water escapes from the drum-washer, this is raised, and the spindle bearing the roll is lowered, so as to bring the respective knives closer together, to enable them to cut the reduced material still finer.

Draining.—When the material is sufficiently *broken*, as it is termed, the engine is then emptied by means of its valves, and the contents run into large vats or *drainers*, furnished with perforated zinc floors, in which it is allowed to drain thoroughly; and in order to remove the water more effectually, the pulp is afterwards pressed, either by an extractor or a centrifugal drainer, which dries it sufficiently for gas-bleaching, or for treatment in the *potcher* or *poacher*. This is a larger engine than the washer, and instead of the cylinder and bars, has a hollow drum which carries on its periphery a number of cast-iron paddles, which thoroughly agitate the pulp, and thus render it more susceptible of being freely and uniformly acted upon by the bleaching agent. The drum-washer of this engine should have a finer wire than is used for the breaker.

Torrance's Drainer.—This machine, which has been extensively used, is manufactured by Messrs. J. Bertram and Son, of Edinburgh. It consists of a perforated cylindrical box, enclosed in a fixed case, which revolves at about two hundred and fifty revolutions per minute. The machine is capable of treating about 4 cwt. of pulp per hour.

CHAPTER V.

TREATMENT OF ESPARTO.

Preliminary Treatment.—Picking.—Willowing Esparto.—Boiling Esparto.—Sinclair's Esparto Boiler.—Roeckner's Boiler.—Mallary's Process.—Carbonell's Process.—Washing Boiled Esparto.—Young's Process.—Bleaching the Esparto.

Preliminary Treatment: Picking.—Esparto is imported in bales or trusses, tightly compressed by hydraulic presses, and bound with twisted bands of the same material, much in the same manner as hay, except that which comes from Tripoli, which is bound with iron bands. The bands being cut, the loosened material is then spread out upon tables, partly covered with iron, or galvanised-iron, netting, to allow earthy matter or sand to pass through to a receptacle beneath. Here it is carefully picked by women and girls, who remove all roots, other kinds of grass, weeds, and heather. The material thus cleansed from impurities is transferred to the boiling-room. This careful preliminary treatment has been found necessary, since pieces of root and other vegetable matters which may be present are liable to resist the action of the bleaching liquor to a greater extent than the grass itself, and therefore produce specks, or "sheave" as they are termed at the mill, in the manufactured paper.

At some mills, however, as at the Horton Kirby Mills of Messrs. Spalding and Hodge, at South Darenth, for example, the cleaning of esparto is admirably effected by means of a willow, or esparto-cleaner, constructed by Messrs. Masson, Scott, and Bertram, which entirely supersedes the system of hand-picking. Having recently visited the mill referred to, we were enabled, through the courtesy of Mr. Sydney Spalding, to witness the action of this willow, which appeared to perform its functions with perfect uniformity, and to clean the grass most effectually. The *rationale* of the operation of willowing esparto may be thus described:—

Willowing Esparto.—A bale of the grass is unbound at a short distance from the machine, and the grass, which is in the form of small bundles or sheaves, tied with bands of the same material, is thrown by a woman on to a table or platform placed by the side of the willow, and a second woman, standing near the hopper of the machine, takes the bundles, a few at a time, and drops them into the hopper. The machine being in motion, in a few moments the grass, freed from its bands and dirty matters, appears in a perfectly loose condition at the wider end of the drum, and passes upward along a travelling-table to a room above, in the floor of which are the man-holes of a series of esparto boilers. During the passage of the loosened fibre, women standing on steps or platforms at the sides of the travelling-table are enabled to examine the material, and to remove any objectionable matters that may be present. Beneath the drum of the machine is a pipe, through which the dust and dirty matters are drawn away by means of a fan.

Boiling Esparto.—In the boiling-room at the mill referred to is a series of vertical stationary boilers, each about twenty feet high, and capable of holding about three tons of grass. The man-holes of these boilers pass through the floor of a room above, being nearly level with it, into which the cleaned esparto is conveyed, as described, by the travelling-table of the willowing machine. In this room is a series of compartments in which the willowed esparto is stored until required for boiling, when it is fed into the boilers by means of two-pronged forks provided for the purpose. The boiler being partially charged with caustic ley at 14° Twad., the esparto is introduced, and steam also, by which the esparto becomes softened, and thus a larger quantity of the fibre can be charged into the vessel. When the full charge of ley and esparto have been introduced the head of the boiler is securely fixed by means of its bolts, and steam then turned on until a pressure of about 20 lbs. to the square inch has been reached, which pressure is kept up for about three hours, when the steam is shut off and the blow-off tap opened. When the steam is blown off, the spent liquor is run off, and hot water then run into the boiler, steam again turned on, and the boiling kept up for about twenty minutes to half an hour, at the end of which time the steam is shut off and the blow-pipe opened. As soon as the steam has blown off, the washing water is run off by the bottom pipe, and the grass allowed

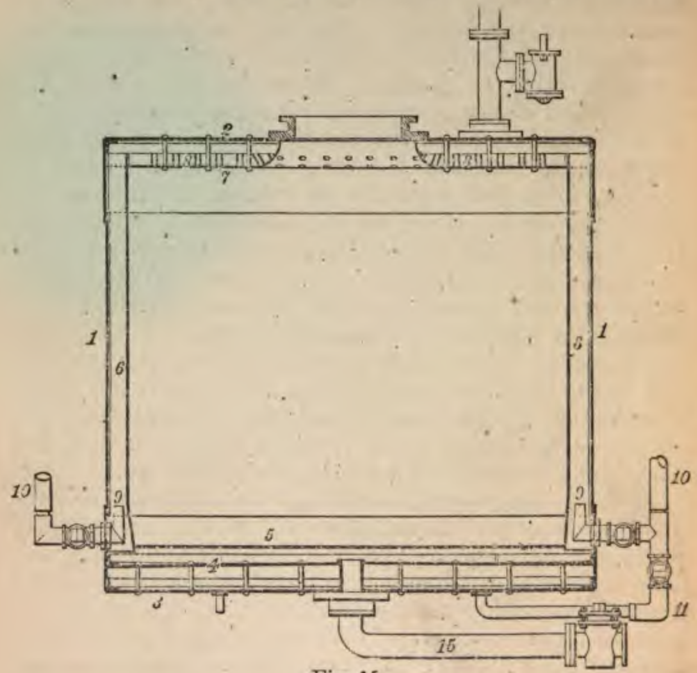


Fig. 15.

to drain as thoroughly as possible. A door at the lower end of the boiler is then opened, and the grass emptied into trucks and conveyed to the washing-engines.

Sinclair's Esparto Boiler.—Another form of boiler, known as Sinclair's boiler, of the vertical cylindrical type, is shown in Figs. 15 and 16. It is constructed on what is termed the "vomiting" principle, but without the central vomiting-pipes generally used, and is fitted with one or more vomiting-pipes close to the side, two diametrically opposite pipes being used by preference. Steam jet pipes, with upwardly-directed nozzles, are fitted into the vomiting-pipes at points a little above the bends, between the vertical and horizontal parts. The liquid or ley thrown up the vomiting-pipes by the action of the steam is delivered from the upper ends of the pipes over a diaphragm or plate fixed near the top of the boiler, and the liquid is

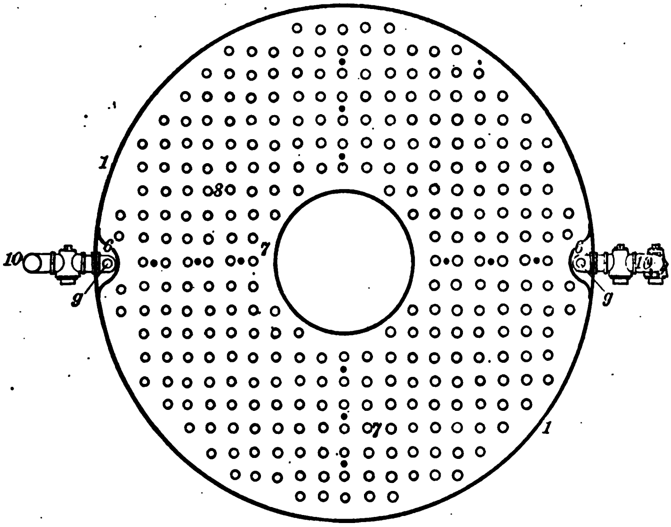


Fig. 16.

retained at a certain depth on the diaphragm by a number of small tubes fixed in it, and the liquid becomes well heated by the steam before overflowing down the tubes, which tubes also serve to distribute it uniformly over the fibrous materials in the boiler. A casing is formed at the bottom of the boiler, and in some cases extended more or less up the sides, and is supplied with steam, which should be superheated, or of high pressure. With this arrangement the heat in the boiler is maintained without the excessive condensation of steam and consequent dilution and weakening of the liquors which occurs in ordinary boilers. Figs. 15 and 16 are horizontal and vertical sections of one form of this boiler. The boiler is made with a vertical cylindrical shell, 1; with a flat top, 2; and flat bottom, 3; and there is an inner or second bottom, 4; the space between it and the bottom, 3, being for steam to assist in heating the contents of the boiler. At a little distance above the inner bottom, 4, there is the usual perforated horizontal diaphragm, 5, down through which the liquid or ley drains from the fibre. Two diametrically opposite vertical vomiting-pipes, 6, are formed by the attachment of curved plates to the cylindrical shell, 1, and these vomiting-pipes, 6, have their upper ends above a horizontal diaphragm, 7, attached by stays to the boiler top, 2. This diaphragm is perforated, and short tubes, 8, are fixed in the perforations so as to project upwards, by which arrangement the liquid, rising up the vomiting-pipes, 6, lies on the diaphragm to the depth of the tubes, 8, and overflows down through them all equally, so as to be uniformly distributed over the materials in the boiler. Steam jet nozzles, 9, are fitted in the lower parts of the vomiting-pipes, being supplied with steam by pipes, 10, from one of which a branch, 11, supplies steam to the double bottom, 3, 4. The steam jets cause the liquid to be drawn from under the perforated diaphragm, 5, and thrown up the pipes, 6, whereby a constant circulation of the liquid through the fibre is maintained. The liquors are drawn off by the pipe, 15. In another form of boiler

Mr. Sinclair employs vomit-pipes formed of thin steel plates riveted to opposite sides of the boiler, and the liquid which drains through the perforated double bottom is forced upward through the vomit-pipes to the perforated plates above, through which it distributes over the material in fine jets. The boiler is capable of holding from 2 to 3 tons of esparto, and under a pressure of from 40 to 50 lbs. the boiling occupies about two hours.

Roeckner's Boiler.—This boiler, of which an illustration of two in series is given in Fig. 17, has been extensively adopted by paper manufacturers. It will be noticed that the vomit-pipe A is placed outside the boiler, and the steam enters at the cock B, forcing the liquor up the vomit-pipe A and distributing it over the esparto. A pipe C is used for heating the liquor by means of waste steam at the commencement of the operation. The grass is fed into the boiler at the opening D. At E E are gauges for showing the height of the liquor in the boiler. F F F are pipes for the supply of steam, strong ley, and water, and the door G is for the discharge of the boiled grass. Each boiler is capable of holding 3 tons of esparto, and the boiling is completed in about two and a half hours, at

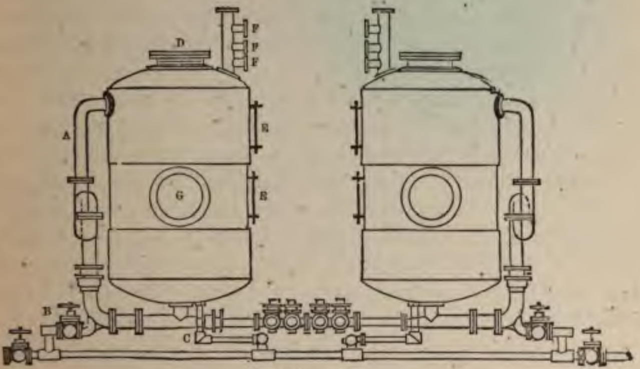


Fig. 17.

a pressure of from 35 to 40 lbs. per square inch. It is said that the boiler effects a saving both in time and the amount of soda used.

Mallary's Process.—By this process the inventor says that he obtains the fibre in greater length, and gets rid of the gummy and resinous matters in a more economical way than by the present system. The materials used form a species of soap, with which and with the addition of water, the esparto is boiled. To carry out his process, he places in a boiler a suitable quantity of water, to which caustic soda, or a ley of the required strength to suit the nature of the fibre, is added; magnesite, or carbonate of magnesia, in the proportion of about 2 per cent. of the fibrous material, or a solution of sulphate of magnesia, is then added and mixed with the ley. He next adds "an improved saponaceous compound" to produce the required result, and when the boiling is completed, the stuff is treated as ordinary stock, to be applied for paper-making or other uses. The proportions are as follows:—2 gallons of petroleum or its products, 1 gallon of mustard oil, 10 to 15 lbs. of caustic soda, and 1 per cent. of boracic acid. These are placed in a copper and heated for 1 to 2 hours, until properly saponified. From 3 to 6 gallons of the "saponaceous compound" are added to the ley and magnesite, previously placed in the boiler with the fibre, and the boiling is kept up for the usual length of time, when the fibre will be found "beautifully soft, and the greater portion of the gum, silica, and resinous matters removed, or so softened as to be no hindrance to the perfect separation of the fibres, whilst the strength, silkiness, and softness are preserved in all their natural integrity." Considering that caustic soda ley "of the required strength" forms an essential part of this process, we should imagine that the auxiliaries mentioned would scarcely be necessary.

Carbonell's Process.—In this process, devised by M. Carbonell, of Paris, 200 lbs. of raw esparto are placed in a wooden vat furnished with a perforated steam-pipe, 20 lbs. of soda and 30 lbs. of quicklime being mixed with it:

the vat is then supplied with cold water until the esparto is completely covered. Steam is then turned on, and the materials boiled for 4 hours. The spent liquor is then drained off, and the esparto submitted to hydraulic pressure. It is afterwards washed and broken in a rag engine, and in about 15 minutes is reduced to half-stuff. 20 lbs. of chloride of lime dissolved in water are then introduced, and the cylinder kept in motion as usual. In another vessel, lined with lead, 1¼ lb. of sulphuric acid is dissolved in 3 lbs. of water, and this gradually added to the pulp, which immediately assumes a reddish colour; but in the course of about three quarters of an hour it becomes perfectly white, when the pulp is ready for the paper-maker.

In the boiling of esparto, several important points have to be considered. The kind of esparto to be treated is the first consideration, since this grass differs materially in character in the different countries from which it is imported. Spanish esparto is considered the best for paper-making, as it is stronger in fibre and yields a whiter pulp than other varieties. Of the African espartos there are several varieties, which are known respectively as Oran, Tripoli, Sfax, Gabes, and Susa. Of these, the first-named (Algerian esparto) is held in highest estimation amongst paper-makers, since it more closely resembles Spanish esparto than the other varieties, though not so hard and stiff as the latter. These grasses usually have a length of about 10 to 12 inches. Tripoli esparto has an entirely different growth, being sometimes as long as 2½ or 3 feet, and proportionately stouter, and is also softer than Oran esparto, which is not so hard as the Spanish variety. Tripoli esparto does not yield a strong paper by itself, but in conjunction with Oran esparto gives more favourable results. Sfax and Gabes espartos have a closer resemblance to Oran than Tripoli, but are not so strong as Oran, being green and spongy, and not so dry as the latter variety. Susa esparto of good quality is said to equal Oran, but not to yield so high a percentage of fibre.

The next important consideration is to determine the percentage of caustic alkali which should be used per hundredweight of the particular variety of esparto to be treated, and we cannot do better than give the following proportions recommended by Mr. Dunbar.

Fine Spanish	18 to 20	lbs. of 70	per cent.	caustic soda	per cwt.
Medium Spanish	16 to 18	,,	,,	,,	,,
Fine Oran	18	,,	,,	,,	,,
Medium Oran	16 to 17	,,	,,	,,	,,
Susa	18	,,	,,	,,	,,
Tripoli	19 to 20	,,	,,	,,	,,
Sfax	20 to 21	,,	,,	,,	,,

Mr. Dunbar says that the above figures "insure a first-class boil, with the steam pressure of 25 lbs. and not exceeding 30 lbs., but are liable to alteration according to circumstances—such as the form of boilers, quality of the water for boiling purposes, and steam facilities, which ought at all times to be steady and uniform to get the absolute regularity required."

Respecting the strength of caustic ley used for boiling esparto, as indicated by Twaddell's hydrometer, this appears to range from 7° to 15°, some preferring to boil with stronger liquors than others. The time occupied in boiling also varies at different mills, and depends greatly upon the character of the boiler used. We are informed that a Sinclair boiler will turn out, on an average, three boils in twenty-four hours, including filling, boiling, discharging, &c., the boiling occupying about four hours for each batch of grass.

The boiling being completed, the liquor is run off into tanks, to be afterwards treated for the recovery of the soda, and the esparto is then subjected to a second boiling with water only for about 20 minutes. The liquor from the second boiling is sometimes thrown away, even when the soda from the first liquor is recovered; but a more economical method is to use this liquor, in lieu of water, strengthened with soda for a first boiling; or to mix it with the first liquors and evaporate the whole together.

The second boiling being finished, the steam is turned off, and water then run in and steam again turned on for a short time, and the water then run off and the esparto allowed to drain thoroughly. The boiled grass is then discharged into trucks which convey it to the washing engines.

The liquor resulting from the boiling of esparto, which is of a dark brown colour, contains nearly all the soda originally used, but it also contains silicious, resinous, and other vegetable matters which it has dissolved out of the grass, the silica taking the form of silicate of soda. The esparto liquor, which was formerly allowed to run to waste, polluting our rivers to a serious extent, is now treated by several ingenious methods for the recovery of the soda with considerable advantage alike to the manufacturer and the public. The process consists essentially in boiling down the liquor to dryness, and incinerating the residue. During the process of incineration the carbonaceous matter extracted from the grass is converted into carbonic acid, which, combining with the soda, reconverts it into carbonate of soda, which is afterwards causticised with lime in the usual way, and the caustic soda thus obtained is again used in the boiling of esparto. Although one or other of the "recovery" processes is adopted at a good many of our paper-mills, the recovery of the soda is by no means universal as yet, but the time will doubtless soon arrive when the economical advantages of the process will be fully recognised. Indeed, we know it to be the fact that some manufacturers are watching, with keen interest, the progress of some of the newer systems of soda recovery, with the full intention eventually of adopting one or other of them.

Washing Boiled Esparto.—This operation is usually performed in engines similar to those used in washing rags, but in some mills the boiled grass is washed in a series of tanks, so arranged that water flows in at one end of the series, thence passing in succession through each batch of grass in the other tanks, and finally issues at the farthest end of the series as a very concentrated liquor. By this arrangement there is great economy of water, while at the same time no loss of fibre occurs. The concentrated washing liquors thus obtained may be evaporated, and the alkali recovered, which would be an undoubted saving, since these liquors obtained in the ordinary way by washing in the boilers are generally run off as waste. The engines used for washing esparto and converting it into half-stuff are generally of large size, and capable of treating a ton of boiled esparto. In this engine, however, there is no bed-plate, as the action of the roll alone is sufficient to reduce the boiled and softened esparto to half-stuff. A drum-washer is also furnished to the engine, which carries off the dirty washing water, while an equivalent proportion of clean water is kept constantly running into the engine from an elbowed pipe at its end. In charging the washing-engine, it is first about three parts filled with water, when the washing cylinder is lowered, and the esparto is then put in, care being taken not to introduce more of the material than will work freely under the action of the roll; if the mass be too stiff, portions of the material may be imperfectly washed. While the washing is in progress, the workman, armed with a wooden paddle, constantly stirs the esparto, clearing it away from the sides of the engine, so that none of the material may escape a perfect washing. At the bottom of the engine is a "sand-trap," covered with perforated zinc, through which any sand or other solid particles which may be present escape. When the washing is complete, the fresh water supply is shut off, and the drum-washer allowed to run until enough water has been removed to make room for the bleaching liquor.

Young's Process.—By this process the boiled and strained esparto is passed through elastic covered rollers, so adjusted as to split up and squeeze out the dissolved matters or liquid from the fibres, thus leaving them clean and open for the access of the bleaching liquor.

Bleaching the Esparto.—It is usual to bleach esparto in the washing engine, for which purpose a tank of bleaching liquor of the required strength (about 6° T. for Spanish) is placed close to the engine, which is provided with a pipe leading to the engine and another pipe proceeding from the tank in which the bleaching liquor is stored. The supply tank is furnished inside with a gauge, divided into inches—each inch representing so many gallons of liquor—by means of which the workman is enabled to regulate the quantity of bleaching liquor he is instructed by the manager or foreman to introduce into the engine. About half an hour after the bleach has become well incorporated with the fibre, sulphuric acid in the proportion of six ounces of the acid (which must be well diluted with water) to each hundredweight of the fibre. The dilute acid should be added gradually, and the proportions given must not be exceeded. The bleaching being completed, the half-stuff is next treated in a machine termed the *presse-pâte*, which not only cleanses the material from sand and dirt, but also separates all knots and other imperfections from the fibre in a most effectual and economical manner. Indeed, we were much struck with the excellent working of this machine at Messrs. Spalding and Hodge's mill, at South Darenth, and the remarkably fine quality of the finished pulp obtained through its agency. The presse-pâte was formerly used in the preparation of pulp from straw, but its advantages in the treatment of esparto are now fully recognised. The apparatus and method of working it may be thus briefly described :—

The machine is on the principle of the *wet end* of a paper machine, and consists of several stone chests for holding the bleached half-stuff, in which are fitted agitators to keep the stuff in suitable condition. From these chests the stuff is pumped into a mixing box, and from thence over a series of sand traps made of wood, and with slips of wood fixed in the bottom, in which any sand present is retained. The stuff then passes into a series of strainers, which, while allowing the clean fibre to pass through, retain all impurities, such as knots, &c., and the clean stuff is allowed to flow on to the wire-cloth in such a quantity as to form a thick web of pulp. A greater portion of the water escapes through the wire-cloth, but a further portion is removed by the passage of the pulp across two vacuum boxes, connected with four powerful vacuum pumps, which renders the half-stuff sufficiently dry to handle; but to render it still more so, it now passes between couch rolls, and is either run into webs, or, as is sometimes the case, it is discharged into boxes, the web of pulp thus treated being about an inch in thickness.

CHAPTER VI.

TREATMENT OF WOOD.

Chemical Processes.—Watt and Burgess's Process.—Sinclair's Process.—Keegan's Process.—American Wood Pulp System.—Aussedat's Process.—Acid Treatment of Wood.—Pictet and Brélaz's Process.—Barre and Blondel's Process.—Poncharac's Process.—Young and Pettigrew's Process.—Fridet and Matussière's Process.

THE advantages of wood fibre as a paper material have been fully recognised in the United States and in many Continental countries, but more especially in Norway, Sweden, and Germany, from whence large quantities of wood pulp are imported into this country. There is no doubt that our home manufacturers have recently paid much attention to this material, and it is highly probable that wood, as an inexhaustible source of useful fibre, will at no distant date hold a foremost rank. Indeed, the very numerous processes which have been patented since the Watt process was first made known, indicate that from this unlimited source of fibre the requirements of the paper-maker may be to a large extent satisfied, provided, of course, that the processes for reducing the various suitable woods to the condition of pulp can be economically and satisfactorily effected. The great attention which this material has received at the hands of the experimentalist and chemist—the terms not being always synonymous—shows that the field is considered an important one, as indeed it is, and if successfully explored will, it is to be hoped, yield commensurate advantages both to inventors and the trade.

The object of the numerous inventors who have devised processes for the disintegration of wood fibre—that is, the separation of cellulose from the intercellular matters in which the fibres are enveloped—has necessarily been to dissolve out the latter without injury to the cellulose itself, but it may be said that as yet the object has not been fully attained by either of the processes which have been introduced. To remove the cellular matter from the true fibre or cellulose, without degrading or sacrificing a portion of the latter, is by no means easy of accomplishment when practised on an extensive scale, and many processes which present apparent advantages in one direction are often found to exhibit contrary results in another. The field, however, is still an open one, and human ingenuity may yet discover methods of separating wood fibre from its surrounding tissues in a still more perfect manner than hitherto.

The various processes for treating wood for the extraction of its fibre have been classified into: (1) chemical processes; and (2) mechanical processes. We will give precedence to the former in describing the various wood pulp processes, since the pulp produced by the latter, although extensively used, is chiefly employed, in combination with other pulps, for common kinds of paper. In reference to this part of our subject Davis says:—"Experience has dictated certain improvements in some of the details of those earlier methods, by which so-called 'chemical wood pulp' is manufactured very largely on the Continent of Europe. . . . . It is possible to obtain a pulp of good quality, suitable for some classes of paper, by boiling the chipped wood in caustic soda, but when it is desired to use the pulp so prepared for papers having a perfectly white colour it has been demonstrated in practice that the action of the caustic soda solution at the high temperature which is required develops results to a certain degree in weakening and browning the fibres, and during the past five years much labour has been expended in the endeavour to overcome the objections named. The outcome of these efforts has been a number of patents, having for their object to prevent oxidation and subsequent weakening of the fibres."

In several of these patents, to which we shall refer hereafter, bisulphite of lime is employed as the agent to prevent oxidation and consequent degradation of the fibres, and in other processes bisulphite of magnesia has been used for the same purpose. Davis further remarks: "Although a common principle runs through all these methods of preparing cellulose from wood, they differ in detail, as in the construction of the digesters employed, methods of treating the wood stock before boiling it in the sulphurous acid solution, and also as regards pressure, blowing off the sulphurous acid gas, etc., but all these processes present a striking similarity to the method patented by Tilghmann in 1867." There can be no doubt that the action of caustic soda, under high pressures, is highly injurious both to the colour and strength of the fibres, and any process that will check this destructive action in a thoroughly practical way will effect an important desideratum.

I. Chemical Processes: *Watt and Burgess's Process.*—This process, which, with some modifications, is extensively worked in America, consists in boiling wood shavings, or other similar vegetable matter, in caustic soda ley, and then washing to remove the alkali; the wood is next treated with chlorine gas, or an oxygeneous compound of chlorine, in a suitable vessel, and it is afterwards washed to free it from the hydrochloric acid formed. It is now treated with a small quantity of caustic soda in solution, which instantly converts it into pulp, which only requires to be washed and bleached, and beaten for an hour and a half in the beating engine, when the pulp is ready for the machine. The wood-paper process as carried out in America has been described by Hofmann, from whose work* we have abridged the following:—

The wood, mostly poplar, is brought to the works in 5-feet lengths. The bark having been stripped off by hand, it is cut into ½-inch slices by a cutter which consists of four steel knives, from 8 to 10 inches wide by 12 to 15 inches long, which are fastened in a slightly inclined position to a solid cast-iron disc of about 5 to 7 feet diameter, which revolves at a high speed, chopping the wood—which is fed to the blades through a trough—into thin slices across the grain. The trough must be large enough to receive the logs, usually 10 or 12 inches thick, and it is set at such an angle that the logs may slide down towards the revolving cutters; this slanting position only assists the movement of the logs, while a piston, which is propelled by a rack, pushes them steadily forward until they are entirely cut up. The piston, or *pusher*, then returns to its original position, fresh wood is put into the trough, and the operation repeated. In this way many tons of wood can be chopped up by one of these cutters in a day. The sliced wood is conveyed by trucks to an elevator by which it is hoisted up two storeys to a floor from which the boilers are filled. The boilers are upright cylinders, about 5 feet in diameter and 16 feet high, with semi-spherical ends, provided inside with straight perforated diaphragms, between which the chips from one cord of wood are confined. A solution of caustic soda, at 12° B., is introduced with the chips, and fires are started in a furnace underneath. At other works the boilers are heated by steam circulating through a jacket which covers the bottom and sides of the boiler.

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* "Practical Treatise on the Manufacture of Paper." By Carl Hofmann, Philadelphia, 1873.

The boiling is continued for about six hours, when the digestion is complete, and the contents of the boilers are emptied with violence, under the pressure of at least 65 lbs. of steam, which had been maintained inside. A large slide valve is attached to the side of each boiler for this purpose close to the perforated diaphragm, and connected by a capacious pipe with a sheet-iron cylinder of about 12 feet diameter and 10 feet high, which receives the contents—pulp, liquor, and steam. The object of these large chambers—one of which serves for two boilers—is to break the force of the discharging mass. The steam passes through a pipe on the top of each, and from thence through a water reservoir, while the liquid containing the pulp flows through a side opening and short pipe into movable boxes, or drainers, mounted on wheels, and each capable of holding the contents of one boiler; these boxes are pushed along a tramway up to the collecting chambers, where the pulp is received. In a building 132 feet long and 75 feet wide, ten digesting boilers are arranged in one straight line, and parallel with the boilers runs the main line of rails, side tracks extending from it to each of the chambers, and a turn-table is supplied at every junction. By this arrangement the drainer waggons can be pushed from the side tracks on to the main line, which leads to the washing-engines in an adjoining room. A system of drainage is established below the tramways, by which all the liquid which drains from the waggons is carried away and collected for treatment by evaporation; these carriers remain on the side tracks until the pulp is ready for the washing-engine.

When the greater portion of the liquor has drained off, warm water is sprinkled over the pulp from a hose for the purpose of extracting all the liquid which is sufficiently concentrated to repay the cost of evaporation—the most advantageous method of recovering the soda. The contents of the waggons—from the same number of boilers—are then placed in two washing-engines, each capable of holding 1,000 lbs. of pulp. After being sufficiently worked in these engines the pulp is transferred to two stuff-chests, and from thence conveyed by pumps to two wet-machines. The screens (strainers) of the wet-machines retain all impurities derived from knots, bark, and other sources, and the pulp, or half-stuff, obtained is perfectly clean and of a light grey colour. The pulp is bleached with solution of bleaching powder like rags, then emptied into drainers and allowed to remain therein with the liquid for twenty-four to forty-eight hours, or long enough to render the use of vitriol in the bleaching unnecessary. The portion of the white pulp which is to be worked up into paper in the adjoining mill is taken from

American Wood-Pulp System.—Another method of carrying out the wood-pulp process has recently been described by Mr. E. A. Congdon, Ph.B.,[*] from which we extract the following:—"Poplar, pine, spruce, and occasionally birch, are used in the manufacture of chemical fibre. Pine and spruce give a longer and tougher fibre than poplar and birch, but are somewhat harder to treat, requiring more soda and bleach. Sticks of poplar, freed from bark, and cleansed from incrusting matter and dirt, are reduced to chips by a special machine having a heavy iron revolving disc set with knives, and are then blown by means of a Sturtevant blower into large stove chambers after passing over a set of sieves having $1\frac{1}{4}$-inch for the coarse and $1\frac{1}{8}$-inch mesh for the fine sieves, from whence they pass to the digesters, which are upright boilers 7 by 27 feet, with a manhole at the top for charging the chips and liquor, and a blow-valve at the bottom for the exit of the boiled wood. A steam-pipe enters at the bottom, beneath a perforated diaphragm, and keeps the liquor in perfect circulation during the boiling of the wood by means of a steam-ejector of special construction."

Boiling.—The average charge of wood for each digester is 4·33 cords,[†] giving an average yield of 4,140 lbs. of finished fibre per digester. A charge of 3,400 gallons of caustic soda solution of 11° B. is given to each digester charged with chips, and the manhead is then placed in position and steam turned on. Charging the digester occupies from thirty to forty-five minutes, and steam is introduced until the gauge indicates a pressure of 110 lbs., which occupies about three hours. This pressure is kept up for seven hours, when it is reduced by allowing the steam to escape into a large iron tank which acts as a separating chamber for the spent liquor it carries, the steam entering in at one end and passing out at the other through a large pipe, the liquor remaining in the tank. The steam is allowed to escape until the pressure is reduced to 45 lbs., when the digester is blown. The blow-cap being removed, the blow-valve is raised and the contents of the digester are discharged into a pan of iron covered with a suitable hood. The contents strike against a dash-plate placed midway in the pan, which thoroughly separates the fibres of the wood. The time occupied in the foregoing operations is from eleven to eleven and a half hours. It takes from nine to ten hours to free the pans from alkali, when they are removed to washing-tanks with perforated metal bottoms, where the material receives a final washing before being bleached.

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[*] *School of Mines Quarterly, a Journal of Applied Science.* Jan., 1889.

[†] The *cord* is a pile containing 128 cubic feet, or a pile 8 feet long, 4 feet high, and 4 feet broad.

Washing.—Each of the three digesters has a pan into which its contents are discharged, and there are also four iron tanks used for holding the liquors of various strengths obtained from the cleansing of the pulp and a fifth tank is kept as the separating-tank before mentioned. When the digester is blown, the pulp is levelled down with a shovel, and the liquor from the separating-tank is allowed to flow into it. The contents of the next strongest pan are pumped upon it, while at the same time the strongest store tank flows into this pan. This flowing from the tank to the pan, pumping from here to the pan just blown, and from there to the evaporators, is kept up until the liquor is not weaker than 6° B. hot (130° F.). The second pan is now down to 4° B. hot, and the process of "pumping back" is commenced. The two weakest tanks are put upon this pan and pumped out of the bottom of it into the two tanks in which are kept the strongest liquors. The two weak tanks have been filled in the process of completing the cleansing of the third pan (the weakest) on which water was pumped until the last weak tank stood at only ½° B. This pan, now cleaned, is hosed and pumped over to the washing tanks. A fresh blow is now made in this pan, and the same treatment kept up as with the first pan.

The foregoing system is thus illustrated by Mr. Congdon:—

Pan A.—Just blown.
,, B.—Partly cleaned.
,, C.—Almost cleaned.

Tank 1.—3½° B. hot.
,, 2.—2° ,, ,,
,, 3.—1° ,, ,,
,, 4.—½° ,, ,,

Separating tank, strong.

A is levelled down; contents of separating-tank allowed to flow upon it; B is pumped on to A; at the same time liquor from the two strong store tanks is put on it (B), and this continued to be sent from A to the evaporator until it is now weaker than 4° B. hot; the process of "pumping back" is then commenced. The two weakest are allowed in succession to flow on to it, and the liquor purified from the bottom of B into the two strong tanks, filling No. 1, the stronger, before No. 2. The weakest are filled in the process of completing the cleansing of C, on which water is pumped until the last tank from it tests only ½° B. C is now hosed and pumped over to the washing tanks. A fresh digester is blown in C, and the process repeated as with A.

The above system has been modified by having an extra pan into which the liquor from the last pan blown (after sending to the evaporators until down to 6° hot, and bringing down to 4° hot, by the stored liquor) is pumped. When the strength is reduced to 4° the pumping is stopped. The liquor from this pan is put in the next pan blown, after the liquor from the separating-tank has been put upon it, whereby an economy in time is effected.

The pulp, after being partially cleaned in the pans, still contains an appreciable quantity of soda. It is hosed over to the washing-tanks and receives a final washing with hot water. When the pulp is thoroughly free from alkali, and the water flowing from under the tank is colourless, the contents are hosed down by hot water into the bleaching-tanks. The superfluous water is removed by revolving washers, and about 1,000 gallons of a solution of chloride of lime at 4° B. are then introduced, and the contents agitated as usual. The bleaching occupies about six or seven hours, when the pulp is pumped into draining tanks, where it is left to drain down hard, the spent bleach flowing away. The stock is then hosed and pumped into a washing-tank, where it acquires the proper consistency for the machine. From here it is pumped into the stuff chest, whence it goes over a set of screens and on to the machine, from which the finished fibre is run off on spindles. The rolls are made of a convenient size to handle, averaging about 100 lbs. each. The fibre is dried on the machine by passing over a series of iron cylinders heated by steam. The finished product is a heavy white sheet, somewhat resembling blotting paper. The whole of the foregoing operations are stated to occupy forty-five hours.

Aussedat's Process.—By this method the wood is disintegrated by the action of jets of vapour. In one end of a cylindrical high-pressure boiler, about 4½ feet in diameter and 10 feet high, is fixed a false bottom, whereby the wood placed upon it may be removed from the liquor resulting from steam condensed in the chamber, the whole being mounted on lateral bearings which serve for the introduction of the vapour, and the wood is fed through a manhole at the upper end of the boiler. Taps are fixed at the upper and lower ends for the liquid and uncondensed vapour. The wood having been placed in the boiler, the jet is gradually turned on in such a way that at the end of three or four hours the temperature becomes about 150° C., the pressure being about five atmospheres, which point is maintained for an hour. As the slightest contact between the wood and the condensed water would at once discolour the former, it is essential that the liquid be removed from time to time by one of the outlets provided for the purpose.

The treatment above described is said to be suitable for all kinds of wood, and although it is the usual practice to introduce it in logs about a yard long, any waste wood, as chips, shavings, etc., may be used. It is preferable, though not necessary, to remove the bark, but all rotten wood may be left, as it becomes removed in the condensed water. The logs, after the above treatment, by which the fibre is disintegrated and the sap and all matters of a gummy or resinous nature are removed, are afterwards cut up by any suitable means into discs of about an inch, according to the nature of the fibre required. These are then introduced into a breaker, in which they become converted into half-stuff, which, after being mixed with a suitable quantity of water is passed through mills provided with conical stones, in which it becomes reduced to whole-stuff. The pulp thus prepared is principally used in the manufacture of the best kinds of cardboard, but more particularly such as is used by artists, since its light brownish shade is said to improve the tone of the colours. Bourdillat says that in the above process the vapour has a chemical as well as a mechanical action, for in addition to the vapour traversing the cellular tissues of the wood and dissolving a considerable portion of the cell-constituents, acetic acid is liberated by the heat, which assists the vapour in its action on the internal substance of the wood.

Acid Treatment of Wood.—A series of processes have been introduced from time to time, the object of which is to effect the disintegration of wood fibre by the action of acids. The first of these "acid processes" was devised by Tilghmann in 1866, in which he employed a solution of sulphurous acid; the process does not appear to have been successful, however, and was subsequently abandoned, the same inventor having found that certain acid sulphites could be used more advantageously. Other processes have since been introduced, in which wood is treated in a direct way by the action of strong oxidising acids, as nitric and nitro-hydrochloric acids, by which the intercellular matters of the wood become dissolved and the cellulose left in a fibrous condition.

Pictet and Brélaz's Process.—By this process wood is subjected to the action of a vacuum, and also to that of a supersaturated solution of sulphurous acid at a temperature not exceeding 212° F. In carrying out the process a solution of sulphurous acid is used, consisting of, say from $\frac{1}{5}$ to $\frac{1}{3}$ lb. avoirdupois of sulphurous acid to each quart of water, and employed under a pressure of from three to six atmospheres at 212° F. Under these conditions the cementing substances of the wood "retain their chemical character without a trace of decomposition of a nature to show carbonisation, while the liquor completely permeates the wood and dissolves out all the cementing constituents that envelop the fibres." In carrying out the process practically, the wood is first cut into small pieces as usual and charged into a digester of such strength as will resist the necessary pressure, the interior of which must be lined with lead. Water is then admitted into the vessel and afterwards sulphurous acid, from a suitable receiver in which it is stored in a liquid form until the proportion of acid has reached that before named, that is, from 100 to 150 quarts of the acid to 1,000 quarts of water. The volume of the bath will be determined by the absorbing capacity of the wood, and is preferably so regulated as not to materially exceed that capacity. In practice it is preferable to form a partial vacuum in the digester, by which the pores of the wood are opened, when it will be in a condition to more readily absorb the solution and thereby accelerate the process of disintegration. When disintegration is effected, which generally occurs in from twelve to twenty-four hours, according to the nature of the wood under treatment, the liquor, which is usually not quite spent in one operation, is transferred to another digester, a sufficient quantity of water and acid being added to complete the charge. In order to remove the liquor absorbed by the wood, the latter is compressed, the digester being connected with a gas-receiver, into which the free gas escapes and in which it is collected for use again in subsequent operations. The bath is heated and kept at a temperature of from 177° to 194° F. by means of a coil in the digester supplied with steam from a suitable generator. The wood, after disintegration, undergoes the usual treatment to convert it into paper pulp, and may thus be readily bleached by means of chloride of lime. The unaltered by-products contained in the bath may be recovered and treated for use in the arts by well-known methods.

Barre and Blondel's Process consists in digesting the wood for twenty-four hours in 50 per cent. nitric acid, used cold, by which it is converted into a soft fibrous mass. This is next boiled for some hours in water and afterwards in a solution of carbonate of soda; it is then bleached in the usual way.

Poncharac's Process.—In this process cold nitro-hydrochloric acid (aqua regia) is employed for disintegrating wood in the proportions of 94 parts of the latter to 6 parts of nitric acid, the mixture being made in earthen vessels capable of holding 175 gallons. The wood is allowed to soak in the acid mixture for six to twelve hours. 132 lbs. of aqua regia are required for 220 lbs. of wood. When it is desired to operate with a hot liquid, 6 parts of hydrochloric acid, 4 parts of nitric acid, and 240 parts of water are used in granite tubs provided with a double bottom, and it is heated by steam for twelve hours and then washed and crushed.

Young and Pettigrew's Process.—These inventors use either nitric or nitrous acids, and the acid fumes which are liberated are condensed and reconverted into nitric acid.

Fridet and Matussière's Process.—This process, which was patented in France in 1865, consists in treating wood with nitro-hydrochloric acid, for which purpose a mixture of 5 to 40 per cent. of nitric acid and 60 to 95 per cent. of hydrochloric acid is used, which destroys all the ligneous or intercellular matter without attacking the cellulose. After the wood (or straw) has been steeped in the acid mixture, the superfluity is drawn off, and the remaining solid portion is ground under vertically revolving millstones. The brownish-coloured pulp thus obtained is afterwards washed and bleached in the usual way.

It is quite true that cellulose can be obtained from wood and other vegetable substances by treatment with nitric acid alone, or with a mixture of nitric and hydrochloric acids, but it will be readily seen that the employment of such large quantities of these acids as would be required to effect the object in view on a practical scale, would be fraught with incalculable difficulties, amongst which may be mentioned the insuperable difficulty of obtaining vessels that would resist the powerful corrosive action of the acids. Moreover, since nitric acid forms with cellulose an explosive substance (*xyloidin*) of the gun cotton series, the risk involved in the drying of the cellulose obtained would be quite sufficient to forbid the use of processes of this nature.

CHAPTER VII.

TREATMENT OF WOOD (*continued*).

Sulphite Processes.—Francke's Process.—Ekman's Process.—Dr. Mitscherlich's Process.—Ritter and Kellner's Boiler.—Partington's Process.—Blitz's Process.—McDougall's Boiler for Acid Processes.—Graham's Process.—Objections to the Acid or Sulphite Processes.—Sulphite Fibre and Resin.—Adamson's Process.—Sulphide Processes.—Mechanical Processes.—Voelter's Process.—Thune's Process.

Sulphite Processes.—An important and successful method of treating wood has been found in employing sulphurous acid, combined in certain proportions with soda, lime, or magnesia, whereby a bisulphite of the alkaline or earthy base is obtained. One of the principal attributes of these agents is that in boiling wood at high pressures oxidation and consequent browning of the fibres is prevented. Of these sulphite, or more properly bisulphite, processes, several of those referred to below have been very extensively adopted, and vast quantities of so-called "sulphite pulp" are imported into this country from Norway, Germany, Scandinavia, &c., the product from the latter source being considered specially suited for the English market. Some of these processes are also being worked in this country, but more particularly those of Partington, McDougall, and Ekman.

Francke's Process.—In this process, which is known as the "bisulphite process," the active agent employed for the disintegration of wood is an acid sulphite of an alkaline or earthy base, as soda or potassa, lime, &c., but it is scarcely necessary to say that the process has since been modified by others. The invention is applicable to the treatment of wood, esparto, straw, etc., and may be thus briefly described:—A solvent is first prepared, which is an acid sulphite of an alkali or earth, that is, a solution of such sulphite with an excess of sulphurous acid. As the cheapest and most accessible base the inventor prefers lime. It has long been known that a solution of sulphite of lime, combined with free sulphurous acid, would, at a high temperature, dissolve the intercellular portions of vegetable fibres, leaving the fibres in a suitable condition for paper manufacture; but Mr. Francke claims to have determined the conditions under which this can be effected with rapidity, and in such a way as to preserve the strength of the fibres, and to have obtained a practical method of preparing pulp by his process. For his purpose he employs a moderately strong solution of the solvent at a high temperature, with gentle but constant agitation. The acid sulphite is produced by this process at small cost and at a temperature nearly high enough for use in the following way:—A tower or column is charged with fragments of limestone, which are kept wetted with a shower of water; fumes of sulphurous acid, produced by burning sulphur, or by roasting pyrites, etc., are then passed through the tower. The liquid which collects at the bottom of the tower is the desired solvent, which should have a strength of 4° to 5° B. It is not essential that the limestone should be pure, as magnesian limestone, etc., will answer equally well. The soluble alkalies, as soda and potassa, may also be used when their greater cost is not an objection. But for these alkalies the treatment is modified, as follows:—The tower is charged with inert porous material, such as coke, bricks, etc., and these are kept wetted by a shower of caustic alkali at 1° to 2° B., while the sulphurous acid fumes are passed through the tower. In like manner carbonate of soda or potassa may be used, but in this case the solution showered on the porous material should be stronger than that of the caustic alkali, so that it may contain approximately the same amount of real alkali. Whichever alkaline base be employed, the liquid collected at the bottom of the tower should have a strength of 4° to 5° B this being the acid sulphite of the base is used as the solvent employed for the manufacture of pulp. When wood is to be treated, it is freed as much as possible from resinous knots by boring and cutting them out, and is then cut—by preference obliquely—into chips of a $\frac{1}{4}$ to $\frac{3}{4}$ of an inch thick. Esparto, straw, and analogous fibres are cut into fragments. The fibrous material and solvent are charged into a digester heated by steam at a pressure of four or five atmospheres, and consequently capable of raising the temperature of the contents to about 300° F. As agitation greatly promotes the pulping of the materials, Mr. Francke employs a revolving cylindrical boiler, which is allowed to revolve while the charge is under treatment.

Ekman's Process.—In this process, which in some respects bears a resemblance to the preceding, native carbonate of magnesia (magnesite) is first calcined to convert it into magnesia; it is then placed in towers lined with lead, and sulphurous acid gas, obtained by the burning of sulphur in suitable furnaces, is passed through the mass, a stream of water being allowed to trickle down from the top of the towers. The supply of gas is so regulated that a continual formation of a solution of bisulphite of magnesium, of an uniform strength, is obtained; great care, however, is necessary to avoid excess and consequent loss of sulphurous acid by its conversion into sulphuric acid. In boiling, the fragments of wood, previously crushed by heavy rollers, are placed in a jacketed, lead-lined, cylindrical boiler, suspended on trunnions, so that it can be inverted to remove the charge. The pressure in the outer jacket is 70 lbs. per square inch, and that within the boiler is 90 lbs. per square inch. The boiling occupies twelve hours. This process has been extensively worked by the Bergvik and Ala Company, of Sweden, for many years with great success, and we understand that the company has been turned over to an English company—the Bergvik Company, Limited. The Ilford Mill and Northfleet Works have been largely supplied with sulphite pulp from the Swedish works.

One great drawback to the bisulphite processes is that the boiling cannot be effected in iron boilers unless these be lined with some material which will protect the iron from the destructive action of the bisulphite, which, being an acid salt, would exert more action upon the iron than upon the fibre itself, and the solution of iron thus formed would inevitably prove injurious to the colour of the fibre. In several of the systems adopted iron boilers lined with lead have been used, but the heavy cost of this material and its liability to expand unequally with the iron, especially at the high temperatures which the solvent necessarily attains under pressure, causes the lead to separate from the iron, while it is apt to bulge out in places, and thus becomes liable to crack and allow the acid liquor to find its way to the interior of the iron boiler which it was destined to protect. To overcome this objection to the simple lead lining, Dr. Mitscherlich patented a process which has been extensively adopted in Germany, and is now being carried out by several companies in different parts of America. This process is briefly described below.

Dr. Mitscherlich's Process.—The digester employed in this process is lined with thin sheet lead, which is cemented to the inner surface of the boiler by a cement composed of common tar and pitch, and the lead lining is then faced with glazed porcelain bricks. In this process a weaker bisulphite of lime is used than in Francke's, and the time of boiling is consequently considerably prolonged.

Ritter and Kellner have proposed to unite the inner surface of the boiler to its lead lining by interposing a soft metal alloy, fusible at a temperature lower than that of either metal, and it is claimed that the iron and lead are thus securely united, while the alloy being fusible under the normal working temperature of the digester, the lead lining can slide freely on a boiler shell.

Partington's Process.—This process, which has been for some time at work at Barrow, and for the further development of which a private company, entitled the Hull Chemical Wood Pulp Company, Limited, has been formed, consists in the employment of sulphite of lime as the disintegrating agent. The process consists in passing gaseous sulphurous acid—formed by burning sulphur in a retort, into which is forced a current of air at a pressure of 5 lbs. to the square inch—through a series of three vessels, connected by pipes, the vessels being charged with milk of lime. The first two of these vessels are closed air-tight, and the gas is then introduced, while the third vessel remains open; from this latter a continuous stream of nitrogen escapes, due to the removal of the oxygen by the burning sulphur from the air passed into the retort. This process is said to be a very economical one, so far as relates to the cost of materials used.

Blitz's Process.—This process consists of employing a mixture composed of bisulphite of soda 2 parts, caustic soda 1 part; and vanadate of ammonia 1 gramme, in hydrochloric acid 4 grammes to every 6 kilogrammes of the bisulphite. The wood, after being cut up in the ordinary way, is submitted to the action of the above mixture, under a pressure of three or four atmospheres, for from four to eight hours, and the pulp is then ground; it is said to possess some of the qualities of rag pulp and to look much like it.

McDougall's Boiler for Acid Processes.—This invention is intended to obviate the difficulties which arise in using lead-lined boilers, owing to the unequal expansion and contraction of the lead and the iron on their being alternately heated by steam and cooled, on the discharge of each successive batch of pulp. This invention consists in constructing the boilers with an intermediate packing of felt, or other compressible and elastic material, so that when the interior leaden vessel is heated, and thereby enlarged and pressed outwards by the steam, the compressible and elastic packing yields to the pressure and expansion. Also in the cooling of the vessels the packing responds to the contraction, and approximates to its original bulk and pressure between the two vessels, and so prevents the rupture or tearing of the lead and consequent leakage and other inconveniences. Another part of this invention consists in the construction of the outer iron or steel vessel in flanged sections, which are fitted to incase the interior leaden vessel with a space between the two vessels, into which the compressible and elastic materials are packed. In the construction of these vessels the iron or steel flanged sections are placed on to the leaden vessel and packed with the compressible and elastic lining in succession. As each section is packed it is screwed close up to the adjoining section by the screw bolts, fitted into corresponding holes in the flanges of the contiguous section until completed. This method of construction secures economy by the retention of the heat, which is effected by the packing between the two vessels. The materials used for the packing are caoutchouc, felt, flocks, asbestos, etc., and a space of about two inches between the vessels is preferred, into which the packing is filled.

Graham's Process.—This process consists in boiling fibrous substances in a solution of sulphurous acid, or a sulphite or bisulphite of soda, potash, magnesia, or lime, or other suitable base and water. The boiling is preferable conducted in a closed boiler, lined with lead, to protect it from the action of the chemical substances used, and is fitted with a valve which can be opened to allow the gases and volatile hydrocarbons contained in and around the fibres to escape. The method of carrying out the process has been thus described:—" In carrying out the process there is a constant loss of sulphurous acid gas going on, and consequently a continual weakening of the solution employed, to avoid which it is preferable to employ monosulphite of potash, soda, magnesia, lime, or other suitable base, and water. Either of these substances, or a suitable combination of them, and water are placed in the boiler with the fibrous substances to be treated, and the temperature raised to the boiling point. After the hydrocarbons, air, and gases natural to the fibrous substances have been driven out by the heat and allowed to escape, sulphurous acid, in its gaseous or liquid state, or in combination with either of the bases referred to, is pumped or injected into the boiler. There is thus forming in the closed boiler a solution containing an excess of sulphurous acid above that required to form, in combination with the base, a monosulphite. The operation of injecting sulphurous acids, or the sulphites, may be repeated from time to time during the boiling, so as to fully maintain, and if necessary increase, the strength and efficiency of the chemical solution. It is said that by this process a saving of the chemicals employed is effected, as little or no sulphurous acid gas is lost during the time the gaseous hydrocarbons, air, and other gaseous matters are being expelled from the fibrous materials. If an open vessel is used instead of a closed boiler, it will be necessary to keep the solution at a fairly uniform strength, and if necessary to increase the strength, but the result will be substantially the same; but as it is evident that, when using an open boiler, the excess of sulphurous acid supplied during the boiling will be constantly driven off as gas, it must be replaced by further injections, while the acid fumes may be conveyed away and condensed, so as to be available for further use. When the fibrous substances are boiled as above, with the addition of potash, soda, etc., during the boiling, the result will be equally beneficial. The inventor prefers to inject the sulphurous acid or its combinations into the boiler at the bottom, and to cause it to come in contact with the solution therein before reaching the fibrous materials. For this purpose there is formed a kind of chamber beneath the boiler, but separated from it by a perforated disc or diaphragm of lead or other suitable material not acted upon by the solution, so as to allow the latter to fill the chamber, to which is connected a pipe, through which the sulphurous acid or solutions of the sulphites is forced by any suitable apparatus.

Objections to the Acid or Bisulphite Processes.—While the various methods of boiling wood in caustic soda at high temperatures are well known to be open to serious objections, the acid treatment of wood also presents many disadvantages, which it is to be hoped may be yet overcome. In reference to this, Davis makes the following observations:—"In the acid treatment of wood for the purpose of converting the fibres into pulp for use in paper manufacture, the general practice has been to use alkaline solutions of soda, combined in various proportions with certain acids, such, for instance, as sulphurous acid, hydrochloric acid, etc. These solutions have been heated in digesting vessels, and the high temperature resulting from this process of heating developing a pressure of from six to seven atmospheres, the wood being disintegrated by the action of the boiling solutions, the gum, resinous constituents, and other incrustating or cementing substances that bind the fibres together are decomposed, destroyed, or dissolved, while pure cellulose, which constitutes the essential element of the ligneous fibres, is separated therefrom. To this end high temperatures had to be employed, otherwise the disintegration was found to be only partial, the wood remaining in a condition unfit for further treatment. The high temperature not unfrequently converts a large proportion of the resinous and gummy constituents of the wood into tar and pitch—that is to say, carbonaceous bodies that penetrate into the fibre and render its bleaching difficult, laborious, and costly, while the frequent washing and lixiviation necessary to bleach such products seriously affect the strength of the fibre and its whiteness, and also materially reduce the percentage of the product, in some instances to the extent of 18 per cent. These difficulties and detrimental results materially enhance the cost of production, while the fibre itself suffers considerably in strength from the repeated action of the chloride of lime. . . . The difficulties are chiefly due to the carbonisation of certain constituent parts of the fibres under temperatures exceeding 212° F., such carbonised matters being insoluble and incapable of being bleached, and as they permeate the fibre, cannot be entirely removed.

"To overcome these difficulties, the wood should be product would be recovered, which merely requires to be dissolved out for further use. There are, however, several important objections to the use of sulphides in this way, amongst which may be mentioned the deleterious vapours which they emit; and this alone would doubtless prevent their employment—at all events in this country.

II. Mechanical Processes.—Besides the various chemical methods of separating cellulose from woody fibres, before described, certain processes have been devised for reducing wood to the condition of pulp directly by mechanical means without the aid of any chemical substance whatsoever. In this direction Heinrich Voelter, of Wurtemburg, appears to have been the first to introduce a really practical process for the conversion of wood into pulp for paper-making, although, as far back as 1756, Dr. Schaeffer, of Bavaria, proposed to make paper from sawdust and shavings mechanically formed into pulp: the process was not successful, however, with the machinery then at his command.

Voelter's Process for Preparing Mechanical Wood Pulp.—In 1860-65 and 1873 Voelter obtained patents in this country for his methods of treating wood mechanically, and the process may be thus briefly described:—Blocks of wood, after the knots have been cut out by suitable tools, are pressed against a revolving grindstone, which reduces the material to a more or less fine condition, but not in a powdery form, and the disintegrated fibre is caused to press against a wire screen, which allows the finer particles to pass through, retaining the coarser particles for further treatment.

The apparatus employed, which is shown in Fig. 17A, consists of a pulping apparatus A, with vat K, in which the revolving stone S is placed; the blocks of wood are held against the stone at *p p*, and water is introduced at G, and the revolving stone carries the pulp against the screen E, which admits the passage of the finer particles of the wood, while the coarser particles are led by the trough F to the first refining *cylinder* B, after passing through an oscillating basket, which retains the coarser particles. From thence it is led through a distributing apparatus and hopper C, to be uniformly supplied to the refining cylinder D, these cylinders being of the ordinary construction, and, as usual, covered with fine gauze wire sieves. The ground material which fails to pass through the sieves is transferred by an elevator to the millstones E, which are of ordinary construction, and after leaving these unites with the finer fibres which pass through E, the whole now entering a mixing reservoir F, whence it is thrown on to the cylinder G, and the pulp which passes into this is distributed on to a similar cylinder H, the contents of which then passes through the last cylinder I, which is differently constructed to the others, inasmuch as its lower part is surrounded by an impervious leather jacket, so that the pulp ascends in order to enter it. The disintegrated fibres that are retained by the wires of the cylinders pass into the refiners, which consist of a pair of horizontal cylinders of sandstone, one of which (the upper one) only revolves, and by the action of these the coarser fibres become further reduced, the finer particles, as before, passing through the wire gauze of the cylinders, the operation being repeated in the same order until the whole of the fibres have passed through the sieves.

Thune's Process.—Mr. A. L. Thune, of Christiana, U.S.A., has recently patented an apparatus for disintegrating wood, which consists of a grinding apparatus connected to a turbine. In this arrangement the grindstone, fixed on a shaft, is worked by a turbine, and the wood, which is used in small blocks, is pressed against the stone by means of a series of hydraulic presses. The fine pulp is afterwards made into thick sheets by means of a board-machine, the pulp, mixed with water, passing down a shoot into a vat beneath, in which is a revolving cylinder covered with wire-cloth, which in its revolution carries with it a certain quantity of pulp in a continuous sheet; this is taken on to an endless travelling belt by means of a small couch-roll, and passes on to a pair of rolls, round the upper one of which the sheet becomes wound, and is removed when sufficiently thick.

CHAPTER VIII.

TREATMENT OF VARIOUS FIBRES.

Treatment of Straw.—Bentley and Jackson's Boiler.—Boiling the Straw.—Bertrams' Edge-runner.—M. A. C. Mellier's Process.—Manilla, Jute, etc.—Waste Paper.—Boiling Waste Paper.—Ryan's Process for reating Waste Paper.

Treatment of Straw.—As a paper-making material, the employment of straw is of very early date, a patent for producing paper from straw having been taken out by Matthias Koops as far back as 1801. The material, however, was used in its unbleached state, and formed a very ugly paper. White paper was not obtained from straw until 1841, but no really practical method of treating this material was devised until about ten years later, in France, when MM. Coupier and Mellier introduced a process which, with subsequent modifications, has been extensively adopted. A great advance in the manufacture of paper from straw has since been effected by the introduction of various boilers, specially constructed for boiling the material at high pressures, and for keeping the alkaline liquors freely circulated amongst the fibre during the progress of the boiling. These boilers are of different forms—being either cylindrical or spherical—and are preferably of the revolving type, which causes the caustic ley employed in the boiling to become uniformly mixed with the fibre. Sometimes the vomiting boilers described elsewhere are used by paper-makers in preference to those referred to.

Bentley and Jackson's Boiler.—This boiler, a representation of which is shown in Fig. 18, is 7 feet in diameter, 18 feet long on the cylindrical surface, with hemispherical ends of Martin-Siemens steel plate $\frac{7}{16}$ inch thick in the shell, and $\frac{1}{2}$ inch thick in the ends. It is double riveted in the longitudinal seams, has two manholes 3 × 2, forged out of solid steel plate. Inside are two perforated lifting plates or shelves, each 1 foot wide, $\frac{1}{4}$ inch thick, the full length of the shell, and secured to the ends by strong angle-irons; it is supported on two turned cast-iron trunnions. These boilers are tested by hydraulic pressure to 120 lbs. per square inch.

The varieties of straw generally used for paper-making in this country are wheat and oats, though rye and barley straws are also used, but in a lesser degree. The treatment of straw differs greatly at different mills, some makers using strong liquors and boiling at a lower pressure, while others prefer to use less caustic soda and boil at a higher pressure. There can be little doubt, however, that the high temperatures resulting from boiling at very high steam pressure must deteriorate the fibre considerably, causing subsequent loss of fibre in the processes of washing and bleaching.

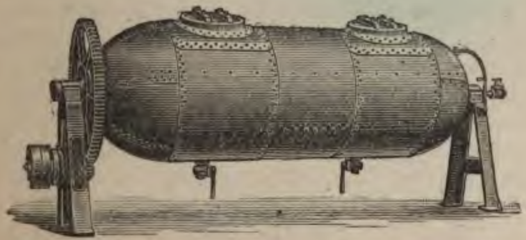

Fig. 18.

Boiling the Straw.—The straw is first cut into short lengths of one or two inches by means of a chaff-cutter, or by a machine similar to a rag-cutter, and the cut material is then driven by an air-blast through a wooden tube into a chamber having coarse wire-gauze sides: a second chamber surrounds this, in which the dust from the straw collects as it passes through the wire gauze. The winnowed straw, freed from dust and dirt, is then conveyed in sacks to the boilers. In charging the boilers, a certain quantity of ley is first introduced, and steam also, and the cut straw then added, which soon becomes softened, and sinks to the bottom of the boiler, when further quantities of the material are added, until the full charge has been given. The requisite proportion of ley and water is then run in and the head of the boiler secured in its place. Steam is now turned on, until a pressure of 20 to 40 lbs., or even more, has been reached, when the boiling is kept up for 3½ to 8 hours, according to the pressure used and the strength of the alkaline liquor, which varies from 9° to 16° Tw. From 10 to 20 lbs. of caustic soda per cwt. of straw are generally required to boil the material thoroughly. The boiling being complete, steam is turned off, and when the boiler has somewhat cooled, the material, which is in the form of a pulp, is discharged by the pipes beneath into a large tank or strainer, the bottom of which is fitted with a series of plates having long narrow openings or slits, through which the liquor drains. The pulp is then washed with water, and again allowed to drain thoroughly, after which it is dug out and transferred to the potcher to be again washed and bleached. At some mills the straw is boiled whole and not subjected to any preliminary cutting. In such cases the boiled straw, not being so fully pulped as when cut into short lengths, is emptied from the boiler through the manholes used for charging the material into the boiler.

Bertrams' Edge-runner.—For the purpose of crushing the knots of the straw, and other hard particles derived from weeds, etc., a machine termed the "kollergang" or "edge-runner" is sometimes employed. This machine, which is manufactured by Bertrams, Limited, and of which an illustration is given in Fig. 19, consists of two large millstones, made from hard red granite, the surfaces of which are sometimes grooved with V-shaped equidistant grooves. These stones are worked by a horizontal spindle, and are caused to revolve very rapidly in an iron basin, in which the washed pulp is placed, and by this means the knots and harder portions of the fibre not fully acted upon by the caustic alkali, become so reduced as to be more readily accessible to the action of the bleach, and thus a very superior straw pulp is produced. In using this machine in the way indicated, the washed pulp is mixed in a chest pro-

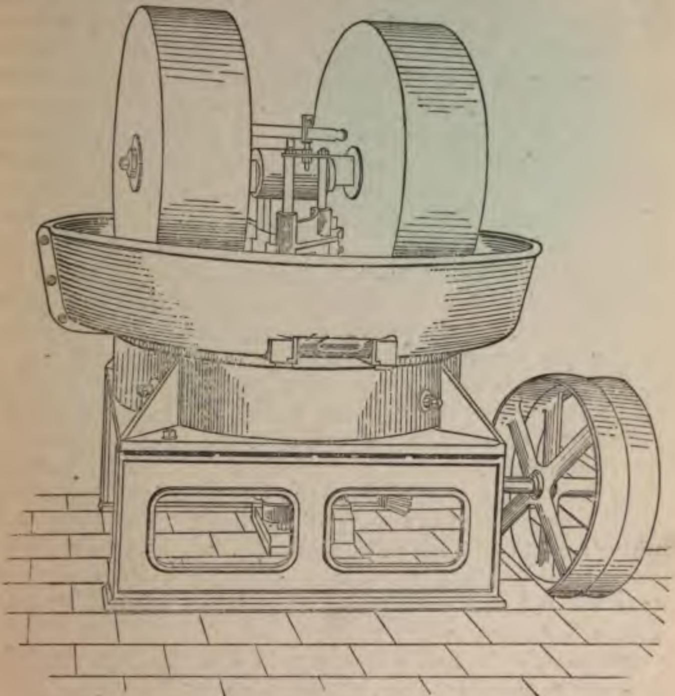

Fig. 19.

vided with agitators, with water, is then pumped into a second chest above it, from whence it flows into the basin shown in the engraving, while the stones are revolving.

M. A. C. Mellier's Process.—By this method the straw is first cut into small lengths as usual; it is then steeped for a few hours in hot water, and afterwards placed by preference in a jacketed boiler, the object being to heat the materials without weakening the ley by the direct introduction of steam into the body of the material. The boiler is to be heated to a pressure of 70 lbs. to the square inch, or to a temperature of about 310° F., by which means, it is said, a considerable saving of alkali is effected, as also time and fuel, as compared with the ordinary practice of boiling. The alkaline ley which M. Mellier prefers to use is from 2° to 3° B., or of the specific gravity of from 1·013 to 1·020, and in the proportion of about 70 gallons of such solution to each cwt. of straw. The boiler should revolve very slowly, making about 1 or 2 revolutions per minute. The boiling occupies about 3 hours, at the pressure named, when the steam is turned off and cold water passed through the jacket of the boiler, which assists in cooling the pulp, the water thus used being afterwards employed in washing the pulp. The pulp is then thoroughly washed until the last water runs off quite clear, when it is next steeped for about an hour in hot water acidulated with sulphuric acid, in the proportion of about 2 per cent. of the weight of the fibre. The pulp is then washed with cold water, when it is ready for bleaching in the usual way.

Manilla, Jute, etc.—Previous to boiling these fibres it is usual to cut them into short pieces by a machine such as is used for cutting straw, after which they are cleaned in a willowing and dusting machine. The boiling is then conducted in the same way as for esparto. Manilla fibre is not so much used in this country as in the United States, where its employment forms an important feature in the manufacture of certain kinds of paper. Some idea of the extent to which it is used by the paper-makers of

America may be gleaned from the following statement of Mr. Wyatt:—"Another large and important branch of the American paper trade are the mills running on news and Manilla paper. Many of these mills turn out a vast quantity of paper, running up to two hundred tons per week, besides making their own ground wood pulp. The American news is composed mainly of ground wood pulp, with an admixture of about 15 to 25 per cent. of sulphite wood or jute fibre, and not much loading, and the machines are run at high speed. What is termed Manilla paper is very largely used in the States, and much more so than with us for common writings, envelopes, and wrapping papers. The paper is composed of Manilla, jute fibre, old papers, etc., and is highly finished at the machine. I was told of one mill belonging to a large company running altogether six mills on news and Manilla, turning out, with one 96-inch machine and beater capacity of 1,800 lbs., and one Jordan, 10 to 12 tons of 2,000 lbs., of Manilla paper per day at an average speed of 200 feet per minute."

Jute is seldom reduced to the condition of a fine white pulp since the treatment necessary to obtain that condition would result in a weak fibre; it is usual, therefore, to only partially reduce the material, when a strong fibre is obtained, which, lacking in whiteness, is used for coarse papers. This also applies to Adamsonia, or Baobab, another description of bast obtained from the West Coast of Africa. These fibres are chiefly used for papers which require strength rather than whiteness of colour, such as wrapping papers, &c.

"Broke" paper is a term applied to paper which has been imperfectly formed on the paper machine or damaged while passing over the drying cylinders. Imperfect sheets when they are not sold as *retree*, and clean waste paper, also come under this designation and are re-converted into pulp after undergoing the treatment described below.

Waste Paper.—In treating waste paper for conversion into pulp for paper-making, it is doubtless advisable to separate, as far as can be done economically, papers which have been written upon with common ink, as old letters, documents, &c., from printed papers, since the latter require a more severe treatment than the former. While simple boiling in water containing a little soda-ash will discharge ordinary writing ink, printer's ink can only be extracted by using rather strong solutions of soda-ash or caustic soda; and even with this treatment it can only be rendered serviceable for an inferior paper, owing to the grey colour of the resulting pulp, due to the carbon of the printer's ink, upon which the alkali has no solvent effect.

Boiling Waste Paper.—This is sometimes effected in iron vats, about 8 feet deep and 8 feet in diameter at the bottom, and about 6 inches wider at the top. At the bottom of each vat is a false bottom, closely perforated with small holes. Steam is introduced by a pipe below the false bottom, which passes through the perforations and thus becomes uniformly distributed to all parts of the vat. To facilitate the emptying of the vats, the false bottoms have connected to them three or four iron rods, to the tops of which iron chains are hooked, and by this means the false bottom, carrying the mass of boiled paper can be raised by a steam hoisting engine or crane and deposited where desired. When the boiling is commenced, the vat should first be about one-fourth filled with a solution of soda-ash, and the steam then turned on. When the liquor boils, the papers having been previously dusted, are introduced gradually, and well distributed through the liquor; if they are thrown into the vat in large quantities at a time, and especially if they are in a compact state, the portions in contact may not be reached by the liquor, and an imperfect boiling will be the result. To ensure a uniform distribution of the boiling liquor over the surface of the material, an iron pipe extends from the centre of the false bottom to nearly the top of the vat, and this pipe is covered with a hood, which causes the soda liquor to be evenly spread over the whole mass. The vats are either cased with wood or coated with asbestos to prevent the escape of heat, and the vessel is covered with a flat iron cover, which is generally in two halves. The steam enters the tubs at the side, below the false bottom, and the exhausted liquor is drawn off through a valve connected to the bottom of the vat. In some mills the liquor is not drawn off after each boiling, but the boiled paper is hoisted from the vat as before described, and the liquor strengthened by the addition of from 10 to 20 lbs. of soda-ash for each 100 lbs. of the paper to be next boiled. Paper that is thickly coated with printing ink requires an extra dose of soda-ash. The boiling is continued for twelve to twenty-four hours according to the nature and condition of the waste paper under treatment.

Waste papers are frequently boiled, after dusting, in revolving boilers, in a solution of soda-ash or caustic soda, but it not unfrequently happens that some portions of the material become so agglomerated or half pulped during the boiling that the alkali fails to reach all the ink, and as this cannot be removed by the after processes of washing and breaking, it remains in the body of the pulp and necessarily forms a constituent part of the paper to be produced from it. The mass, when discharged from the boiler and drained is then conveyed to the washing-engine, in which it becomes broken and freed from alkali and so much of the ink as may have been dissolved or loosened, and it is afterwards treated in the beater and mixed with varying portions of other paper stock, according to the quality of paper to be produced. In some mills the boiled waste paper is disintegrated after boiling, by means of the edge-runner (Fig. 19).

Ryan's Process for Treating Waste Paper.—The following process for treating waste paper so as to produce a "first-class clean paper" therefrom, was patented by Mr. J. T. Ryan, of Ohio. The waste paper is first passed through a duster in the usual way, all thick old books being previously torn apart to separate the leaves. The papers are then boiled in a hot alkaline liquor without pulping them, whereby the alkali acts on the surfaces of the papers, and dissolves off, carrying away all the ink into the liquor. The papers, which are still in sheet form, are then drained as free as convenient from the alkaline liquor, and are next washed in the washing-engine, which leaves the material perfectly clean. It is then pulped in the beating-engine; and it is claimed that it can be formed into first-class paper without the addition of any new or expensive paper stock. The details of the process are thus given by the patentee: "Into a bucking-keir put a soda-ash solution having a density of 5° B., at 160° F., put in the stock, and shower for eight hours at a temperature of 160° F., without pulping the paper, then lift and drain, and cleanse well in the washing-engine; then pulp and form into paper. As the draining will always be imperfect, each charge removed will carry away some of the soda-ash solution, and leave the remainder of impaired strength. After each drainage add water to make up for loss in quantity of the solution, and add enough soda-ash solution at a density of 13° B., to bring all the liquor up to 5° B. at 160° F. In about eighteen working days the liquor will have accumulated considerable ink and other matter. Then blow one half of the liquor, and restore the quantity for proper working. None of the soda-ash solution is wasted, except such as falls to drain and what is blown out as last mentioned." In carrying out this process every care must be taken to guard against pulping before the alkali is washed out.

CHAPTER IX.

BLEACHING.

Bleaching Operation.—Sour Bleaching.—Bleaching with Chloride of Lime.—Donkin's Bleach Mixer.—Bleaching with Chlorine Gas (Glaser's Process).—Electrolytic Bleaching (C. Watt's Process).—Hermite's Process.—Andreoli's Process.—Thompson's Process.—Lunge's Process.—Zinc Bleach Liquor.—Alum Bleach Liquor.—New Method of Bleaching.

Bleaching Operation.—The half-stuff treated in the breaking-engine is run into the potcher, and the water it contains is lifted out as far as practicable by the washer; the spent liquor from the presses or drainers is then run in in lieu of water, and as much fresh bleaching-liquor as may be required is then measured in, and in from two to six hours the pulp becomes perfectly white. "However well managed a mill may be," says Mr. Arnot, "it is scarcely possible to avoid having a small residue of unused chlorine in the liquid which drains from the bleaching stuff." The rule, therefore, is to use this liquor in the way above indicated, by which the unexhausted chlorine, operating upon fresh half-stuff, becomes available, and is, therefore, not wasted. "That as little of this residual chlorine as possible may remain in the stuff," Mr. Arnot further observes, "when put into the beating-engine, powerful hydraulic presses are employed to compress the stuff and squeeze out the liquid. These presses should be large enough to contain easily the whole contents of a poaching-engine, and of unexceptional workmanship. The perforated lining especially should be carefully prepared and properly secured. I have seen much trouble from negligent workmanship in this respect. Recently I examined a number of samples of press drainings, and found the unexhausted chlorine to vary very much—from a few grains of bleaching powder per gallon to about one ounce."

Sometimes it is the practice to partly fill the potcher with water, and the engine being set in motion, the half-stuff is gradually introduced until the full charge has been given, and the stuff is then washed for some time, after which the drum-washer is raised, and the bleaching liquor then run in, care being taken that the necessary quantity is not exceeded, otherwise the fibre will suffer injury from the chemical action of the bleaching agent. When vitriol is employed to liberate the hypochlorous acid, the vitriol, previously diluted with water, should be placed in a small lead-lined tank in such a position that the acid liquor may slowly trickle into the engine at the rate of 1 lb. of sulphuric acid in twenty minutes. As soon as the bleaching is complete the stuff is emptied into large stone chests, each of which will hold the contents of two engines. On the bottom of these chests are perforated zinc drainers, while a similar drainer runs up the back of each chest. The bleached stuff is allowed to remain as long as may be convenient in these chests, after which it is removed to the beating or refining engines. In some mills the bleaching is effected in the breaking-engine, while at other mills the operation is performed in the beating-engine.

In bleaching it is considered to be more advantageous to employ moderately strong liquors rather than weaker ones, inasmuch as the object is effected in less time than when weaker liquors are employed. An extreme in the opposite direction, however, must be avoided, since a very strong bleach will inevitably cause injury to the fibre. Sometimes the potchers are fitted with steam-pipes, in order that the diluted bleaching liquor may be heated, if required, to facilitate the operation. If the temperature be raised too high, however, the effect upon the fibre will be at least as injurious as if too strong a bleach were employed. It must also be borne in mind that in either case, after the pulp has been bleached and the liquor allowed to run off, the mass has to remain some time—even if pressed to remove as much of the liquor as possible—in direct contact with the products resulting from the decomposition, and probably some undecomposed hypochlorite also, which will continue their chemical action upon the fibre until removed by washing, or neutralised by one or other of the agents employed for the purpose.

Sour Bleaching.—When the bleaching liquor, after acting upon the half-stuff for some time, has become partially exhausted, dilute sulphuric acid—about one part acid to fifteen parts of water—is added, which, by liberating hypochlorous acid, hastens the bleaching considerably, and when the chemical action resulting from this treatment is nearly complete, the spent liquor is allowed to drain away, and fresh bleaching liquor is introduced, the strength being regulated by the progress made in the first case, which will depend upon the character of the fibre treated. In the second application of the bleach no acid is used. When sulphuric acid is added to the bleaching liquor, as above, the process is termed *sour bleaching*. Sometimes hydrochloric acid is used for this purpose, but in either case it is necessary to avoid employing the acid in too concentrated a state, or in too great a quantity, otherwise free chlorine will be liberated, which, besides being injurious to the health of the workmen and the surrounding machinery, also involves loss, while the colour and strength of the fibre itself will also be impaired. In some mills the bleaching is effected in the beating-engine, the bleaching liquor being pumped in while the machine is in motion.

Respecting the time which the bleaching operation should occupy, there appears to be some difference of opinion, or, at all events, the practice seems to vary in different mills, but there is, no doubt, an advantage, so far as ultimate yield is concerned, in moderately slow bleaching at a moderate temperature, inasmuch as there is less risk of chemical action upon the cellulose itself than when strong liquors are used, at a higher temperature, with a view to hasten the operation and economise the bleaching powder.

Bleaching with Chloride of Lime (*Preparation of the Bleaching Liquor*).—Chloride of lime, or hypochlorite of lime, commonly called bleaching powder, when well prepared, contains from 32 to 35 per cent. of active chlorine. Being readily decomposed by the air, and also by heat, this substance should always be stored in a cool and dry place until required for use. A solution of bleaching powder is generally prepared in large tanks lined with lead, which are provided with agitators or stirrers, so that the powder, when added to the water, may be freely diffused, and its active material dissolved in the liquid. A machine, or "bleach-mixer," manufactured by Messrs. Bryan Donkin and Co., of Bermondsey, is shown in Fig. 20, which is so constructed that the strong bleach liquor does not destroy it. The device for agitating the contents of the tank explains the principle of the machine. To prepare the bleaching liquor, about ½ lb.

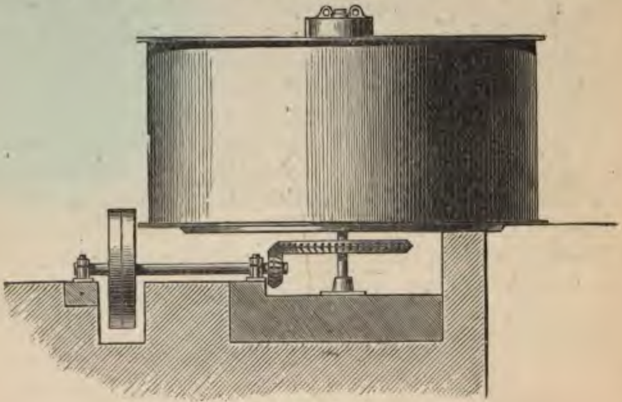

Fig. 20.

of chloride of lime to each gallon of water is used, which yields a liquor at about 6° T. When the required quantity of bleaching powder and water have been introduced into the mixer and sufficiently agitated, the vessel is allowed to rest until the residue, which chiefly consists of free lime and its carbonate, has subsided, when the clear liquor may be run off for use. When all the clear liquor has been drawn off the residue should be washed with water, and after again settling, the washing water run off, and fresh water added, these washings being repeated as often as necessary to remove the last traces of the "bleach," as it is technically called. The washing waters may be used in lieu of water in the preparation of fresh bleaching liquors. In some mills the bleaching powder is mixed with from 2 to 3 times its weight of water; the mixture is then well agitated and the residue afterwards allowed to settle, the clear solution being afterwards drawn off and the residue then washed as before. In either case the residual matter is afterwards well drained and then cast aside. The bleaching liquor is stored in large tanks ready for use, from which it is withdrawn as required by means of a syphon or otherwise.

Bleaching with Chlorine Gas (*Glaser's Process*).—This method of bleaching is not so much adopted in England as formerly, but has found much favour in Germany; indeed, within the past few years, namely, in March 3rd, 1880, a process was introduced by Mr. F. Carl Glaser for treating straw, in which, after boiling with caustic soda as usual, the pulp is bleached by the action of chlorine gas. The straw, after being separated from weeds by a slight or superficial picking, is cut into pieces of from $\frac{1}{3}$ to $\frac{2}{3}$ of an inch in length. The cut straw is then placed in a rotary boiler for about four hours, at a pressure of about 4 to $4\frac{1}{2}$ atmospheres, in a solution composed of 29 lbs. of caustic soda at 71°, and 48 lbs. of calcined soda at 90°, rendered caustic, for every 220 lbs. of straw. After boiling, the dirty ley is drawn off, and the boiled straw subjected to two washings with water. It is then conveyed to the washing-engine, where it is washed for an hour; the drum of the machine should have a sieve or sifter, the apertures of which are about 60 to the square inch. The washed straw is next dried by centrifugal force in a hydro-extractor, until it contains about 70 per cent. of water, which is necessary for the action of the chlorine gas. To effect this, so as to obtain not very solid or close cakes of straw, the holes of the wire of the hydro-extractor should not be more than 50 to the square inch. The cakes of straw thus formed are then exposed to the action of chlorine in leaden chambers of the ordinary kind, in which they are placed in layers upon hurdles, or upon shelves. If the chlorine is produced by hydrochloric acid, for every 220 lbs. of unboiled straw, 51½ lbs. of the acid at 20° B., and a corresponding quantity of 70 per cent. peroxide of manganese are used. After the bleaching operation, the acid formed is removed by washing in a washing-engine. If a complete reduction of the fibres has not been effected by the bleaching, this may be completed by the aid of well-known machines, and either before or subsequent to the after-bleaching there is used for 220 lbs. of straw about 4½ lbs. of chloride of lime, at 35° [per cent. ?] The patentee then gives the following explanation :—"As pine wood or fir is chemically freed from its colouring principle and transformed into fibres as well as cellulose, the object of the intense action of the chlorine is to destroy the mucilage of the straw, as well as the incrusting matters which have not been destroyed by the boiling with caustic soda, and consequently to strip or expose and open the fibres." It will be readily seen that this process bears a close resemblance to Mr. C. Watt's wood-pulp process.

Electrolytic Bleaching (*C. Watt, jun.'s, Process*).—At the present time, when the means of obtaining the electric current for practical purposes in the arts have so far exceeded that which would have been deemed probable some forty years since, we find that many ingenious processes, which were found to be unpractical at that time from the want of cheap electrical power, have since reappeared in the form of patented inventions, which would seem to possess every merit—but originality.

So long ago as September 25th, 1851, the author's brother, Mr. Charles Watt, obtained a patent for, amongst other claims, decomposing chlorides of sodium and potassium, and of the metals of the alkaline earths into hypochlorites by electricity. It may be well to make a few extracts here from his specification in order that some of the subsequent patents, to which we shall refer, may be traced to what may, perhaps, be considered their true origin. In the specification in question, the inventor says:—"The third part of my invention consists of a mode of converting chlorides of potassium and sodium, and of the metals of the alkaline earths, into hypochlorites and chlorates, by means of a succession of decompositions in the solution of the salt operated upon, when induced by the agency of electricity. . . . . Electricity first decomposes the chloride, the chlorine being eliminated at one of the electrodes, and the alkaline or earthy metallic base at the other electrode. . . . . The liberated chlorine will, when it is set free, combine with a portion of alkali or alkaline earth in the solution, and a hypochlorite will be formed. The hypochlorite thus formed will, by the continued action of heat, be resolved partly into a chlorate of the alkali or alkaline earth, and partly into a chloride of the metallic base, and the chloride will again be subjected to decomposition, and a hypochlorite formed. . . . If I desire to produce a hypochlorite of the alkali or earth, I merely keep the vessel warm . . . and continue the process until as much of the saline matter has been converted into a hypochlorite as may be required for the purpose to which the solution is to be applied. This mode of forming a hypochlorite of the alkalies and alkaline earths may be used for preparing a bath for the purpose of bleaching various kinds of goods, and the bath may be strengthened [recuperated] from time to time by the action of the electric current."

Thus it will be seen that this specification clearly described a process by which the chlorides of sodium and potassium, and of the metals of the alkaline earths (chloride of magnesium, for example), may be converted into hypochlorites by electrolysis, and the hypochlorite solution obtained used for the purposes of bleaching. It would appear difficult to conceive how any subsequent patent for accomplishing the same thing, and using essentially the same means, can claim originality in the face of such "prior publication" as was effected by the usual "Bluebook," which any person can buy for eightpence.

Hermite's Process.—The following description of this process has been furnished by the engineers engaged in connection with the process to the *Paper Trade Review*:—"Briefly described, the Hermite process consists in manufacturing a solution of high bleaching power by electrolysing an aqueous solution of magnesium chloride. The salt is decomposed by the current at the same time as the water. The nascent chlorine, liberated from the magnesium chloride, and the nascent oxygen, liberated from the water, unite at the positive pole, and produce an unstable oxygen compound of chlorine of very high bleaching power. The hydrogen and magnesium go to the negative pole; this last decomposes the water and forms magnesium oxide, whilst the hydrogen is disengaged. If in this liquid coloured vegetable fibre is introduced, the oxygen compound acts on the colouring matter, oxidising it. Chlorine combines with the hydrogen to form hydrochloric acid, which finding itself in the presence of magnesium in the liquid combines with it, and forms the initial chloride of magnesium."

Andreoli's Process.—This process consists, avowedly, in bleaching pulps "by means of hypochlorite of sodium, produced by electrolytical decomposition of a solution of chloride of sodium." In carrying out his process, M. Andreoli uses as an electrolyte "concentrated or non-concentrated sea-water, or a solution of chloride of sodium, the specific gravity of which varies according to the quality and nature of the materials to be treated. Generally the solution to be electrolysed works better with a density of 8° to 12° B., but although salt is cheap, and the solution when exhausted may be regenerated by passing an electric current, I always endeavour to have when possible (*sic*) a weak solution, and with some kinds of pulp an electrolyte having the density of sea-water (3° B.) is sufficiently strong to bleach."

The foregoing are the only electrolytic processes for bleaching fibres that need recording, and we fancy there will be little difficulty in tracing the resemblance between the two latter and the process of Mr. C. Watt.

Thompson's Process.—This process, for which a patent was obtained on February 3rd, 1883, may be thus briefly described:—In bleaching linen fabrics the material is boiled for about three hours in a solution of cyanide of potassium or sodium—about half an ounce of the salt to each gallon of water—to remove the resinous matter from the fibre, so that the cellulose may be exposed to the action of the bleach. The fabric is then washed, and again boiled for three hours more in a similar solution, and after being again washed is ready for bleaching. With cotton the preliminary boiling is not necessary, unless the material is greasy, in which case a solution of half the strength and two hours' boiling is sufficient. In ordinary cases cotton is not boiled at all, but is simply washed in cold water and squeezed. In bleaching, all vegetable fibres are treated in the same way, the only difference being in point of time. The cotton or linen, after being treated as described, is then piled somewhat loosely in an air-tight vessel, 9 lbs. of cloth to the cubic foot of space being considered sufficient. The vessel is then filled with a weak solution of bleaching liquor, consisting of about one ounce of dry bleaching powder to each gallon of water. "After the vessel has been filled, the liquor is immediately run out, and is replaced by an atmosphere of carbonic acid, which quickly liberates the chlorine on the fibre, and thus decomposes the water, uniting with the hydrogen and liberating the oxygen, the result of which is to bleach the fibre or fabric. In about an hour the whole of the bleaching liquor in the fibre will have been thus decomposed, and this operation must be repeated until the material is of the proper whiteness to be withdrawn from the action of the chlorine. The material is then washed and squeezed. Chlorine, however, always leaves these materials of a yellowish white." To remove this tint, the material is passed through a solution of oxalic acid—about 2 oz. to the gallon—squeezed as it passes out of this solution, and then passed through another solution made by dissolving ¼ grain of triethyl rose aniline to the gallon of water, or 20 grains of indigo, as may be preferred. To this solution oxalic acid is added until it becomes of an opaque but bright turquoise blue. The material, after washing, is then white.

The patent describes and illustrates the apparatus to be used in conjunction with certain parts of existing apparatus used in bleaching.

Lunge's Process.—In this process acetic acid is used in place of hydrochloric or sulphuric acids, etc., to set free the chlorine or hypochlorous acid, in the ordinary method of bleaching with hypochlorite of lime, or bleaching powder, which, the inventor says, "combines all the advantages of the materials formerly employed, without any of their drawbacks. . . . . The price is no impediment, for a minimal quantity is sufficient, the same being regenerated over and over again. At first acetic acid and chloride of lime decompose into calcium acetate and free hypochlorous acid. In the bleaching process the latter yields its oxygen, hydrochloric acid being formed. The latter instantly acts upon the calcium acetate; calcium chloride is formed and acetic acid is regenerated, which decomposes a fresh quantity of chloride of lime, and so forth. Consequently the smallest quantity of acetic acid suffices for splitting up any amount of chloride of lime. . . . . The hydrochloric acid formed is never present in the free state, as it instantly acts upon the calcium acetate. This is very important, since hydrochloric acid weakens the fibre by prolonged contact, whilst acetic acid is quite harmless. Since there are no insoluble calcium salts present, the operation of 'souring' after bleaching is quite unnecessary; this not merely saves the expense of acid, and of the subsequent washing of the fabrics, but it also avoids the danger, especially present in the case of stout fabrics, of leaving some of the acid in the stuff, which concentrates on drying and weakens the fibre; it may also prove injurious in subsequent dyeing operations. But in the new process no free acid is present except acetic acid, which has no action upon fibre, even in its concentrated state and at a high temperature."

The acetic acid may be employed in various ways, including the following:—A small quantity of the acid may be added from the first to the bleaching liquor; or the fabric, after being treated in the ordinary way with a solution of the bleaching powder, may be steeped, without previous washing, in water containing a little acetic acid; or the fabric may be steeped in water acidulated with acetic acid, and bleaching liquor afterwards run in slowly and gradually, with continuous agitation in the usual way. In the case of hard water, or of impure bleaching liquors, a good deal of the acetic acid would be consumed in neutralising the lime; in this case, some hydrochloric or sulphuric acid may be added, but only sufficient for the purpose, so that no acid but hypochlorous or acetic acid exists in the free state. The process is applicable to the bleaching of vegetable fibres, whether spun or in the unspun state, and for bleaching paper pulp made from rags, wood, straw, esparto, etc. Besides acetic acid, any other weak organic acid of an analogous nature may be used.

Zinc Bleach Liquor.—Strong acids are often objectionable for liberating chlorine from bleaching powder, and especially in bleaching some classes of paper pulp. If a solution of sulphate of zinc be added to one of bleaching powder, sulphate of lime is precipitated, and the zinc hypochlorite formed at once splits up into zinc oxide and a solution of free hypochlorous acid. Chloride of zinc acts similarly; for a saturated solution of zinc in hydrochloric acid decomposes as much bleaching powder as half its weight of concentrated oil of vitriol.—*Varrentrapp.* Consequently zinc salts can be employed in place of sulphuric acid, and thus bleach the paper pulp very quickly. When this mixture is employed in bleaching pulp, the precipitated sulphate of lime resulting from the reaction and also the oxide of zinc formed, remain in the pulp, and serve as loading materials.

Alum Bleach Liquor.—Orioli [*] recommended for use, in paper-mills especially, a bleach liquor made by decomposing equivalent quantities of a solution of chloride of lime and sulphate of alumina, formerly known as *Wilson's Bleach Liquor*. Sulphate of lime is precipitated, and hypochlorite of aluminium remains in solution; this being a very unstable salt can be applied for bleaching without the addition of an acid, splitting up into aluminium chloride and active oxygen. Consequently the liquid always remains neutral, and the difficulty caused by the obstinate retention of free acid in the fibre, by which it is strongly acted upon in drying, in this case does not exist. The aluminium chloride also acts as an antiseptic, so that the paper stock may be kept for many months without undergoing fermentation or other decomposition. The solution is allowed to act for about ten minutes in the engine.—*Lunge.*

New Method of Bleaching.—Young's Paraffin Oil Company have recently introduced what they term an "intermediate oil for paper-making," to be used with alkali in the boiling of rags and esparto, for the purpose of increasing the bleaching power of the powder, and producing a softer pulp, at the same time having no smell. Several well-known paper-makers have tried, and speak favourably of it. The quantity of oil to be added to the caustic varies for different stock, but may be said to average about 1½ gallon per ton.[†]

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[*] Wagner's "Jahresb." 1860, p. 188.

[†] *Paper-Makers' Monthly Journal*, March 15th, 1889.

CHAPTER X.

BEATING OR REFINING.

Beating.—Mr. Dunbar's Observations on Beating.—Mr. Arnot on Beating Engines.—Mr. Wyatt on American Refining-Engines.—The Beating Engine.—Forbes' Beating-Engine.—Umpherston's Beating Engine.—Operation of Beating.—Test for Chlorine.—Blending.

Beating.—One of the most important operations in the manufacture of first-class paper is that of *beating*, by which the half-stuff becomes reduced to a fine state of division, and the fibres which, in the condition of half-stuff, are more or less loosely held together in a clotted state, become separated, and are thus put into a condition in which they will intertwine with each other, or *felt*, as it is termed, when submitted to the vibratory motion of the wire-cloth of the paper machine. The beating-engine, or beater, as it is commonly called, much resembles in construction the washing- and breaking-engine, but since it is required to still further reduce the pulp to a condition suitable for paper-making, the knives of this engine are more numerous and are made to revolve more rapidly. In this engine the half-stuff is cleansed from bleach, hydrochloric or sulphuric acid—whichever acid may have been used in the bleaching—chloride of calcium, and the various products resulting from the decomposition of the chloride of lime. In this engine, also, the loading, sizing, and colouring materials are worked up with the pulp, and the stuff fully prepared for its final transfer direct to the paper-machine. Before describing the various forms of beating-engines which have been from time to time introduced, including some of the most recent types, to which special attention will be drawn, we purpose quoting some observations of well-known experts in paper manufacture which will be read with interest, since they fully explain the importance that attaches to the proper manipulation of the beating-engine for the production of paper of high quality.

Mr. Dunbar's Observations on Beating.—There is no operation of the paper-mill that requires more careful attention and experienced judgment than that of beating, or refining, to bring the pulp to the finest possible condition for paper-making; in this department, Mr. Dunbar urges, "none but thoroughly efficient men should be employed, for it is here that the paper is really made—that is, the quality of the paper produced at the paper-machine will be in proportion to the treatment the material has received; and if the half-stuff sent to the beating-engines is not subjected to judicious manipulation and careful preparation for the special paper to be made, all future doctoring will prove unsatisfactory."

Mr. Arnot on Beating Engines.—On this subject Mr. Arnot says:—"Upon the management of the beating-engine the character of the paper produced largely depends. What is wanted is not a mincing or grinding of the fibre, but a drawing out or separation of the fibres one from another; in fact, the name of the machine indicates pretty accurately the nature of the action required—beating. Long, fine fibres can only be produced [obtained] by keeping the roll slightly up off the bed-plate, and giving it time to do the work. Sharp action between the roll and the bed-plate will, no doubt, make speedy work of the fibre, but the result will be short particles of fibre only, which will not interlace to make a strong felt. Indeed, the action I refer to will reduce the long, strong fibre of linen to little better than that of wood or straw. Practice and careful observation can alone make a good beater-man, and for the finer classes of paper none but careful, experienced men should be entrusted with the management of the beating-engine. Sometimes the operation is conducted in two successive engines, the first being called the intermediate beater, but I have hitherto failed to see wherein the advantage of this system lies. The time usually occupied in beating esparto for printing-paper is about four hours, while for rags the time may vary from four to twelve hours, or even more." This, however, depends upon the nature of the rags themselves, and the purposes to which they are to be applied.

Mr. Wyatt on American Refining-Engines.—Referring to the engines adopted in America, Mr. Wyatt says:—"There are various modifications of the original Jordan, the principal ones being the Marshall, Jeffers, and improved Jordan; but I gathered that experience proves the Jordan type to be the most practical and efficient in the end, and is one of the most generally used. One Jordan is required for each machine, refining all the stuff supplied to it. The roll, or plug, runs from 350 to 400 revolutions per minute, the horse-power consumed varying from 25 to 40 horse-power according to the work done, and an engine will do up to 1,000 lbs. of pulp per hour. The time saved in the beating-engine by the use of the Jordan is just about one-third of what would otherwise be necessary, that is to say, pulp requiring otherwise six hours beating only takes four hours if finished in the Jordan. The half-beaten pulp is emptied into a stuff-chest, and the Jordan is furnished with a small stuff-pump and service-box, just as at the paper-machine what the Jordan does not take flows back again into the chest: the pulp from the Jordan is run into the ordinary machine stuff-chests. The finished pulp can be taken from the Jordan at three different levels from the circumference of the roll, or plug. If the pulp is wanted 'free,' it is drawn from the bottom of the engine; if wanted 'wet,' or well greased, it is drawn from the top; and if medium from the centre."

The Beating-Engine.—The ordinary form of beater consists of a cast-iron trough 13 feet 6 inches long × 6 feet 6 inches wide, and the bottom is dish-shaped, so as to prevent the pulp from lodging, which would inevitably be the case if the bottom were flat, as the pulp would be apt to lodge in the angles formed by the junction of the bottom with the vertical walls of the trough. The iron trough is fitted with a cast-iron roll, 3 feet 6 inches × 3 feet 6 inches, which is provided with 69 "roll-bars," or knives, arranged in 23 groups of 3 bars each; this roll is suspended upon a malleable iron shaft 5 inches in diameter, resting upon side levers; suitable gearing is attached by which the roll can be lifted or lowered at will, the action being uniformly equal on both sides, by which the knives of the roll are kept uniform with those of the bed-plate beneath. The bed-plate, furnished with 20 steel knives, of the same length as the roll, is placed immediately beneath the roll. When the knives of the bed-plate are straight they are fitted into the plate-box at an angle, but in some cases they are bent at a slight angle, when they are termed *elbow plates.* There have been, however, many improvements in the beating-engine introduced of late years, some of which are of considerable importance, and to some of these we will now direct attention. Although our own manufacturers have introduced improvements in beaters which have been fully recognised by the trade, the American engineers have not been behindhand in devising modifications which appear to have some important advantages. The Jordan beater, which has been extensively adopted in the States, consists of a roll in the form of a truncated cone, furnished with knives in the usual way; this revolves in a box of a similar form, fitted with knives in the direction of its length, but at slightly different angles. In this engine the stuff enters at the narrow end through a box having an arrangement which regulates its flow, and the pulp is discharged by several openings in the cover at the wider end. In an engine invented by Mr. Kingsland there is a circular chamber furnished with knives covering its sides; between this is a circular plate, also fitted with knives, which revolves. The stuff enters through a pipe in the centre of one of the sides of the chamber, and flows out through an opening in the opposite side.

Forbes' Beating Engine.—This engine, an illustration of which is given in Fig. 21, is manufactured by Bertrams, Limited, of St. Katherine's Works, Edinburgh. The engine has three chambers, two rolls, and a mixing wheel; the rolls, only one of which is uncovered in the engraving, are fixed in the outer channels, and the mixing wheel is placed in the middle channel. By this arrangement the pulp flows alternately into the two outer channels, and after passing through the rolls again it enters the centre channel at the opposite end.

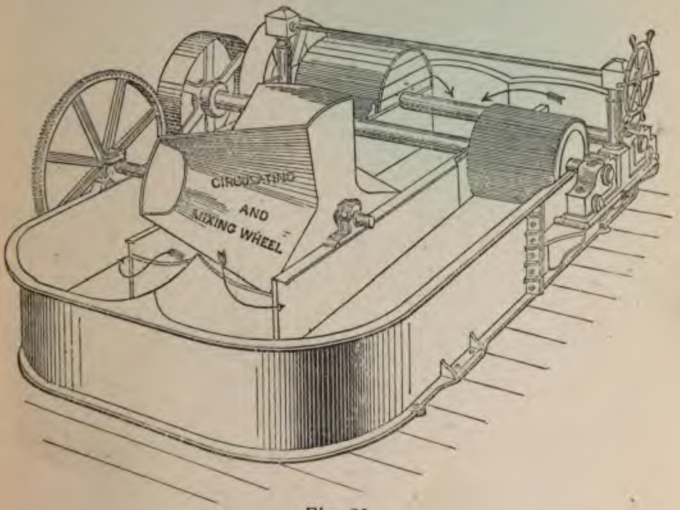

Fig. 21.

Umpherston's Beating Engine.—This engine, for which a patent was granted in 1880, has been successfully adopted at the *Daily Chronicle* and other mills, and presents several important advantages, one of the chief being that it occupies much less ground space than ordinary beating-engines. Indeed, we have heard it remarked of this engine that it will do double the amount of work in the same ground space as the ordinary engine, and this, in some mills, would be a decided advantage. The construction of this beater, a drawing of which is shown in Fig. 22, is thus described by the patentee:—"In the common and almost universal form of engines used for preparing pulp for paper-making, the pulp travels horizontally in a trough with semi-circular ends, and straight sides, partly divided longitudinally by a partition called the midfeather, around which the pulp flows from the back of the roll to its front, where it passes under the roll and over the bottom working-plate, and is again delivered over the back fall to pass again round the midfeather to the front of the roll. In the course of these repeated revolutions part of the pulp near the circumference of the tub has much farther to travel than the part near the midfeather, and consequently is not so often operated upon, and the pulp is thus unequally treated. As an improvement upon this form of tub, I make it so that the pulp

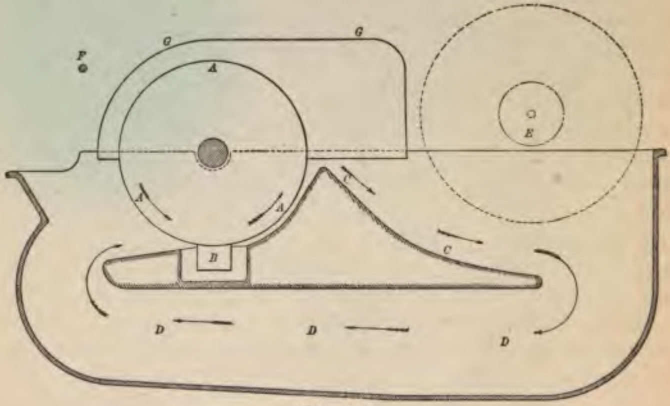

Fig. 22.

passes from the back of the roll to its front through a longitudinal passage under the back fall, the pulp thus moving as through an inverted syphon, the superincumbent weight of the semi-fluid pulp, as delivered over the back fall of the roll, pressing it along this passage and upwards, to enter again in front of the roll. The roll A, bottom plate B, and the form of the back fall C, are similar to those of ordinary engines, but the trough is formed with the passage D under the bottom plate B, so that the semi-fluid contents of the engine, in travelling from the back fall C to the front of the roll A, pass by means of the passage D under the bottom plate B in the direction indicated by the arrows, the superincumbent weight of the semi-fluid pulp, as it is delivered over the back fall C at the back of the roll A, pressing it along the under passage D and upwards to the front of the roll A. The position of a drum-washer is shown at E, and at F is seen a section of the cross shaft for raising or lowering both ends of the roll A simultaneously; G is the roll cover, which may be of any usual form. By this invention the semi-fluid pulp is acted upon in a more effective manner, and its particles are also more equally treated than has hitherto been the case."

The beating-engines are usually driven from a separate engine, but Messrs. Bertrams have introduced a system of direct driving for these engines by which, it is said, there is a considerable saving in power. The accompanying engravings, Figs. 23 and 24, show a series of eight beaters, each carrying 300 lbs. of pulp, driven by one of their compound direct-driving steam-engines, and now being worked at the Forth Paper Mills.

Operation of Beating.—Having referred to some of the more important improvements connected with the beating-engines, we will proceed to explain the operation of beating as briefly as possible. The bleached half-stuff is removed from the tray of the press in caked masses, and in this condition is conveyed in trucks or boxes to the beating-engine. The first thing to be attended to is the removal of the last traces of chlorine from the pulp, which, if not effectually done, would cause injury to the size, and also corrode the strainer plates and wire-gauze of the paper-machine. It is possible to wash out the chlorine by an abundant application of pure water, but this method of removing the chlorine is very tedious and occupies a long time, while it also involves the use of enormous quantities of water—a serious consi-

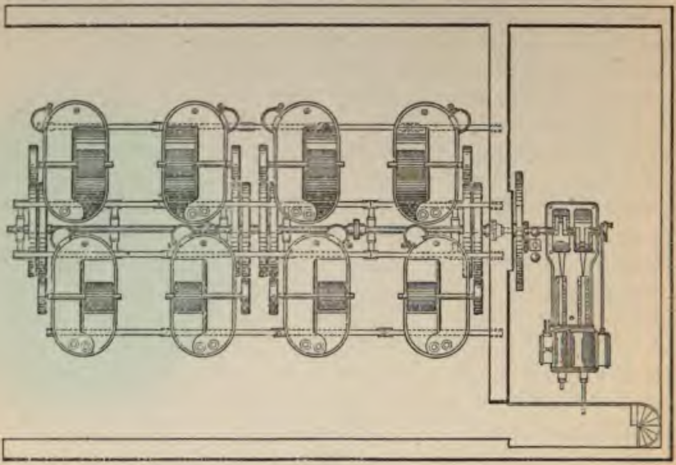

Fig. 23.

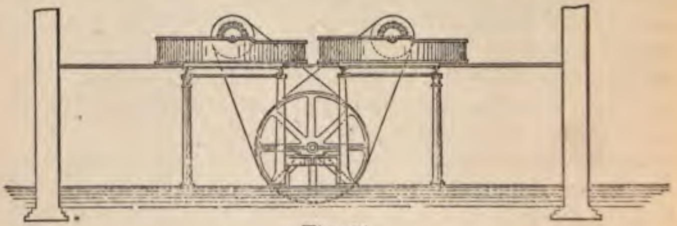

Fig. 24.

deration in some mills; to this may be added the still more important fact that by the method of washing out the chlorine a considerable loss of fibre takes place. The plan most usually adopted is to neutralise the chlorine left in the pulp by the application of suitable chemical agents, whereby the chlorine is rendered inert. These agents, technically termed "antichlors," are sometimes objected to, however, although they are in themselves practically harmless so far as their action upon cellulose is concerned. Mr. Arnot, who has considered this subject very thoroughly, says:—"I do not think there is much in this objection, as those agents that are soluble pass through the wire of the machine almost completely, while those that are insoluble are in the finest possible state of division and pearly white. The chemical agent most largely used is hyposulphite of soda, but hyposulphite of lime is also employed, and those agents, known by the name of 'antichlor,' are put into the engine in such a quantity as will ensure the neutralisation of the whole of the chlorine. The products of the reaction, when the soda salts are used, are chloride of sodium (common salt) and sulphate of soda (Glauber's salt), and, when the lime salt is used, chloride of calcium and sulphate of lime, the latter identical with the pearl hardening so well known as a loading agent." From this it will be seen that little or no harm can possibly occur either to the fibre or the metal work of the machine by the employment of the neutralising agents named, and when it is borne in mind that the simple washing of the pulp would occupy the beating-engine for a lengthened period and exhaust a considerable quantity of water—which, as we have said, would in some mills be a serious matter—the adoption of the neutralising method would undoubtedly have the preference.

The engine, being partly filled with water, is set in motion, and the bleached half-stuff introduced in small quantities at a time, each portion being allowed to become thoroughly mixed with the water before the next batch is added. The charging of the beater with half-stuff is kept up until the mass becomes so thick that it will only just move in the trough under the action of the revolving roll. If the beater is of the older type, portions of the pulp are liable to lodge in corners, to remove which the "beaterman" uses a wooden paddle, with which tool he also pushes the slowly moving pulp in the direction of the roll, especially when the stiff mass appears to move too slowly. At this stage the neutralisation of the chlorine in the pulp is effected, which is done by adding a solution of hyposulphite of soda, a little at a time, until the liquor ceases to redden blue litmus paper, strips of which should be dipped into the pulp every few minutes until the paper persistently retains its blue colour. This operation should be conducted with great care, so as to exactly neutralise the traces of chlorine without adding an excess of the hyposulphite of soda. Besides this salt, other substances are used as "antichlors," as, for example, hyposulphite of lime, which is prepared by boiling milk of lime (slacked lime made into a thin mixture with water) and flour of sulphur in an iron vessel until the latter is dissolved, when, after cooling and settling, the resulting solution, which is of an orange-yellow colour, is ready for use. One great objection to the use of hyposulphite of lime, however, is that when decomposed by the chloride of lime remaining in the pulp sulphur is set free, which, mingling with pulp, will impart to it a yellow tint; besides this, in passing over the drying cylinders of the machine the sulphur present in the paper may attract oxygen from the air, converting it into sulphuric acid, which must inevitably prove injurious to the manufactured paper. Sulphite of soda has also been used as an antichlor, and is said to be preferable to hyposulphite of soda,* inasmuch as the latter salt is liable to decompose with the liberation of free acid, which is not the case with the sulphite of soda.

Test for Chlorine.—Instead of relying solely upon the litmus paper test when applying the antichlor, the following test for chlorine may also be used with advantage:—Take 2 drachms (120 grains) of white starch, and make it into a paste with a little cold water; then pour over it about half a pint of boiling water, stirring briskly; to this add 1 drachm of iodide of potassium, and stir until dissolved and well incorporated with the starch solution. The mixture is then to be allowed to cool, when it is ready for use. A few drops of this mixture dropped upon a small sample of the pulp will indicate if any chlorine be present by the spot assuming a blue colour; if such be not the case, the pulp may be considered free from chlorine.

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* Sometimes also called *thiosulphite of soda.*

During the beating, the roll, which should make not less than 220 revolutions per minute, is lowered, a little at a time, so that the cutting edges of the bars and plate may be brought together gradually and equally until the pulp is reduced to the desired condition. The pulp is made long or short according to the quality of paper to be produced; news papers, which require strength, are made of long-fibred pulp, while writing paper, or paper of fine texture, is made of shorter pulp. The stuff should be what is called "mellowed" in the engine, which is effected by a judicious working of the roll, not lowering it suddenly but gradually, and not much at one time, on the plate, until the pulp attains the fineness required. This is generally arrived at in about three and a half to four hours, though sometimes the beating of pulp from rags is continued for more than double that time. It should be added that if the cutting edges of the roll and plate are brought together suddenly and too closely, the fibre will be cut, and as a consequence the paper produced will be tender.

Esparto, which, in the process of boiling becomes reduced to such a soft condition that the fibres may be readily separated by the fingers, does not require such excessive beating as rags; indeed, the perfect disintegration of the fibres of esparto is practically accomplished in about half the time occupied by rags, and often much less, but this of course depends upon the nature of the esparto itself and upon the thoroughness of the boiling. Wood pulps also require but moderate beating, since the process of disintegration is generally pretty effectually accomplished by the processes to which the raw material is subjected in the course of manufacture into half-stuff, which is the condition in which this paper material is furnished to the manufacturer.

Blending.—To produce papers of the different qualities required by the trade, a system of blending is adopted, which may be effected—(1) by mixing the materials in the raw state, or the rags, previous to boiling; and (2) blending the half-stuff in the beating-engine. The latter method, however, is generally preferred. Sometimes, also, pulps of different character are beaten separately and then mixed in the stuff-chests, where they are mixed as thoroughly as possible before passing on to the machine, but this method would be less likely to ensure a perfect mixture of the respective pulps than would be effected with proper care in the beater. The proportions of the several materials to be blended is also a matter of important consideration. In blending esparto with rag stuff, if the former be in excess it becomes reduced to the proper condition before the latter is sufficiently fine, which causes the rag fibre to appear in "knots and threads" in the manufactured paper. But if the rag stuff be allowed to predominate, the beating is conducted as though no esparto were present, by which, while the rag stuff becomes reduced to the proper length of fibre, the esparto, which is still further reduced, in mingling with the longer fibre of the rags forms what is called a "close" paper. Mr. Dunbar, in his useful little work, "The Practical Paper-maker," furnishes a series of receipts for blending for high-class papers, as also the proportions of colouring matter to be used, which the reader will do well to consult. For news papers, esparto and straw pulps are generally used, in varying proportions according to the nature and quality of the esparto; these proportions have to be regulated according to the judgment of the paper-maker, and vary greatly at different mills. A large quantity of sulphite and other wood pulps are also used, those coming from Scandinavia and Germany being especially suited to the requirements of the English manufacturer. Mechanical wood pulp is also used in a moderate degree—sometimes up to 15 per cent., in some English mills, but it is said that in Germany this paper stock is sometimes used to the extent of 90 per cent.

CHAPTER XI.

LOADING.—SIZING.—COLOURING.

Loading.—Sizing.—French Method of Preparing Engine Size.—Zinc Soaps in Sizing.—Colouring.—Animal or Tub-Sizing.—Preparation of Animal Size.—American Method of Sizing.—Machine-Sizing.—Double-sized Paper.—Mr. Wyatt's Remarks on Sizing.

Loading.—The very finest qualities of paper are usually made without the addition of any *loading*, as it is called, but for most other papers more or less loading material is added, according to the quality of paper to be produced. The loading material used for ordinary qualities is kaolin, or china clay, and for the better qualities sulphate of lime or *pearl hardening*, as it is termed in the trade. China clay, as it occurs in commerce, is in the form of soft lumps and powder, is nearly white, and when rubbed between the finger and thumb should present no hard particles of gritty matter. To prepare it for mixing with the pulp it is first worked up into a thin cream with water, which is usually done in a vessel furnished with an agitating arrangement by which the clay becomes intimately mixed with the water. The cream is then strained through a fine sieve to separate any impurities present, and is then allowed to flow into the beating-engine containing the stuff while in motion, by which it soon becomes mingled with the pulp. The proportion of china clay or other loading material which is to be introduced into the pulp depends upon the quality of the fibre and the requirements of the manufacturer, some makers using less of the material than others. From 3 per cent. to 10 or 15 per cent. appears to be about the extreme range for employing the material as a necessary ingredient in the production of various classes of paper, above which figures the addition of loading material may be considered as an adulteration. Sometimes nearly twice the largest amount named is employed, no doubt to meet the exigences of keen competition—from foreign sources especially.

One effect of the loading, whether it be china clay or sulphate of lime, is to close the pores of the paper, whereby a smoother surface is obtained, while at the same time, if the material has been used in proportions suited to the quality of the fibre, and not in immoderate excess, a stronger paper is produced. A species of asbestos termed *agalite* has been introduced as a loading material, and since it has a fibrous texture, it blends with the fibres of the pulp, forming, as it were, a vegeto-mineral paper. It is stated that as much as 90 per cent. of the agalite used in the beating-engine enters into the manufactured paper, while not much more than half the china clay used is held by the pulp.

Sizing.—"Engine sizing," as it is termed, consists in adding certain ingredients to the pulp while in the beating-engine. The materials generally used are alum and resin soap, in proportions suitable to the paper to be produced. Resin soap is formed by boiling ordinary resin in a jacketed pan such as is used by soapmakers for preparing small quantities of fancy or other soaps, with a solution of soda crystals in the following proportions: Resin, 16 lbs.; soda crystals dissolved in water, 8 lbs.; and the boiling is kept up for about two hours, or until a soap is produced which is perfectly soluble in water. The method of preparing this soap as conducted at the soapworks has been described in the author's work on soap-making,* p. 64, from which the following abstract is taken: "Put into a pan capable of holding about 12 gallons, 2¼ gallons of fresh caustic soda ley at 30° B. Apply gentle heat, and when the ley begins to boil throw in, every few minutes, in small quantities at a time, finely powdered and sifted resin until 37 lbs. have been introduced. The mixture must be well stirred the whole time to prevent the resin from 'clogging' and adhering to the pan. It is important to moderate the heat, as the resin soap has a great tendency to expand and an excess of heat would cause it to boil over. The heat, however, must be kept to near the boiling point, otherwise the mass will become thick and of a very dark colour. When kept at near the boiling point it is always clear and its colour of a reddish yellow. If, during the boiling, the resin soap rises and threatens to overflow, the heat must be checked by throwing in a little cold water, only using sufficient to effect this object. It is absolutely necessary to stir the mass continually, otherwise the resin will agglomerate in masses and thus prevent the alkali from acting freely upon it. The boiling takes about two hours, when the soap is run into an iron frame and allowed to cool. It is very important that the resin used is freed from particles of wood, straw, etc., for which purpose it should be passed through a tolerably fine sieve."

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* "The Art of Soap-making." By Alexander Watt. London, Crosby Lockwood and Son, 4th edition, 1890.

Respecting the preparation of resin soap, Davis says:—"The proportion of resin used to each pound of soda ash varies in different mills, 3, 4, or even 5 lbs. of resin being used to each pound of soda ash. The proportion of resin, soda ash, and water, can be best determined by practical experience, as no prescription could be devised which would be suitable to every case. M. d'Arcet, who modified the proportions recommended by M. Bracconot, recommends for the preparation of resin soap—

Powdered resin	4·80 parts.
Soda crystals at 80° (French alkalimeter) . .	2·22 ,,
Water	100 ,,

Theoretically speaking, only 2·45 parts of alum would be required to precipitate the resin; but the waters, which are almost always calcareous, neutralise part of the alum.

Crystals of soda are much more expensive than soda ash, but on account of their greater purity they are sometimes preferred to the latter. At the present day the resin soap is preferably made by dissolving ordinary resin with a solution of carbonate of soda under boiling heat in a steam-jacketed boiler, the class of paper to be made governing the quantity of resin to be employed. The boiling usually requires from two to eight hours, according to the relative proportions of soda ash and resin used—the greater the proportion of soda used the less time is required for boiling—the process being completed when a sample of the soap formed is completely soluble in water. . . . About 3 lbs. of resin to 1 lb. of soda is the usual proportion. The resin soap is cooled after boiling by running it into iron tanks, where it is allowed to settle, the soap forming a dense syrup-like mass, and the colouring matters and other admixtures of the resin rising to the top are easily removed. It is important to run off the mother liquor (ley) containing the excess of alkali, for when the soap is used it consumes the alum to neutralise it."

When the impurities and ley have been removed the soap is dissolved in water, and if, from imperfect boiling, a portion of the resin is found not to have been saponified, a small quantity of a strong solution of soda crystals is added to the water used for dissolving the soap.

Where starch is used for stiffening purposes, the soap is mixed with a quantity of starch paste in the proportion of 1⅓ part of starch to 1 part of resin soap. Some manufacturers, Mr. Davis states, mix the starch paste with the kaolin in lieu of mixing it with the resin soap. In either case the materials should be thoroughly strained before being added to the pulp. From 3 to 4 lbs. of the mixture of resin soap and starch paste to each 100 lbs. of dry pulp are about the proportions in which the size is generally used, but the quantity added to the pulp in the beater depends upon whether the paper is to be soft-sized or hard-sized.

Sizing is chiefly applied to papers which are to be written upon with ordinary inks, and also, with a few exceptions, to printing papers, the object being to close the pores of the paper and render it non-absorbent, by which the spreading or running of the ink is effectually prevented. While the finest lines may be written upon a well-sized paper (as ordinary writing paper, for example) without spreading in the least degree, a similar stroke of the pen upon blotting paper, tissue, or unsized printing paper would spread in all directions, owing to the highly absorptive property of the cellulose.

The sizing of the pulp is conducted as follows:—After the loading material has been introduced and well mixed, the resin soap, previously dissolved in water, a little carbonate of soda being sometimes added, is mixed with a paste of starch prepared by dissolving starch in boiling water, and the mixture of soap and starch is then passed through a fine sieve to keep back any particles or lumps that may be present. The proportion of the materials used in sizing vary at the different mills, each manufacturer having formulæ of his own; about 1 part of resin size to 3 of starch paste, and, say, from 9 to 12 lbs. of the mixture, may be used for 300 lbs. of pulp; and, if preferred, the respective ingredients may be put into the engine separately, a method adopted at some mills. Some manufacturers of the finest papers, instead of dissolving the starch in hot water, make it into a thin paste with cold water, in which condition it is introduced into the pulp, the object being to impart to the paper a particular feeling to the touch which is not obtainable by other means.

The mixture of resin size and starch paste, with or without the addition of water, is added to the pulp in the beater, in which the pulp is circulating, and the engine allowed to run until the materials are well incorporated in the pulp. At this stage a solution of alum (about 28 to 30 lbs. for 300 lbs. of pulp), or of sulphate of alumina,* is introduced, which causes the resin soap to become "separated," the sulphuric acid of the alum uniting with the alkali of the soap and setting the resin and alumina free in the form of minute particles; the resin in the subsequent drying on the calenders becomes fused, as it were, and thus cements the fibres and alumina together, at the same time rendering them non-absorbent and improved in whiteness by the precipitated alumina. Sometimes ordinary soap is added to the resin soap, which is said to impart a higher finish to the paper in the operation of calendering.

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* Sometimes called "concentrated alum," "pearl alum," etc.

The so-called "concentrated alum," which contains a higher percentage of sulphate of alumina than the crystallised alum, is considered the most economical in use, being proportionately cheaper, and the variety known as "pearl alum" is specially recommended. "Aluminous cake" is another preparation which has found favour in many mills, but since it sometimes contains a large excess of free sulphuric acid it requires to be used with caution, since this acid, although it will brighten the colour of some aniline dyes, will discharge the colour from others, while at the same time it may injuriously affect the brass-wire cloths of the paper machine. The alum solution should be prepared in a lead-lined tank, fitted with a steam pipe for heating the contents when required.

The proportions of the materials used in sizing differ considerably in different mills, but the following may be taken as an average for common writing and printing papers :—

Per 100 parts of dried pulp 10 to 12 parts of resin.
" " " 20 " 30 " starch.
" " " 10 " 12 " alum.

To the sizing solution is generally added from 30 to 50 parts of kaolin. When a colour is present on which alum would have a prejudicial effect this is usually replaced by about one-third of its weight of sulphate of zinc. Many mineral substances have from time to time been added to paper stock, principally to increase its weight, and in 1858 Sholl took out a patent for adding carbonate of lime, a substance which, however, had long been fraudulently used in order to increase the weight, but he found it to have the property of fixing the ink in the pores of the paper, thus rendering it immovable. The only useful addition is kaolin, or some similar aluminous compound, as it attaches itself to the fibre, and, while giving the required opacity and a good surface, takes both printing and writing ink well, and has the advantage, from a manufacturer's point of view, of increasing the weight. It has been proposed that small quantities of glycerine be added to the pulp, in order to give the paper greater flexibility, and especially to give copying-paper the quality of taking up colour readily.*

French Method of Preparing Engine Size.—Thirteen pails of water are boiled in a copper-jacketed pan capable of holding about 150 gallons; 90 lbs. of soda crystals are then introduced and allowed to dissolve, when 200 lbs. of finely-powdered resin are gradually introduced, with constant stirring, and the boiling is sustained for about two hours after the last portion of resin has been added. A further addition of water is now made by putting in five pails of cold water, and the water is then boiled for an hour and a half longer. The resin soap is then transferred to stock-chests, in which it is allowed to remain for ten days or longer, fresh batches being prepared in rotation, to meet the requirements of the mill.

To determine whether an excess of resin soap or of alum has been added to the pulp, red and blue litmus papers should be employed, the former turning blue if an excess of resin soap be present, and the latter red when alum or sulphate of alumina is in excess. For uncoloured papers the aluminous material should be added until the pulp becomes faintly acid, which will be indicated by the blue litmus paper turning slightly red when immersed in the pulp.

Besides resin soap, various substances have been proposed as sizing materials, including wax dissolved in a strong solution of caustic soda and precipitated with alum, but the cost would be an objection to the use of this material except for the highest classes of paper. It is stated that 12 lbs. of gum tragacanth to each 500 lbs. of resin has been used in preparing some kinds of engine-sized papers, and is said to impart to them an appearance equal to that of tub-sized papers.

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* Muspratt's "Chemistry Applied to the Arts."

Zinc Soaps in Sizing.—According to a paragraph in the *Papermakers' Monthly Journal*, a somewhat novel method of sizing is employed in Germany, which consists in the precipitation in the stock of zinc soaps. Cottonseed oil soap or Castille soap is worked up in the engine with the stuff, and after it has become well mixed with the pulp a solution of sulphate of zinc is added, which results in the formation of a white and heavy zinc soap, which is insoluble, and adheres well to the fibres. The weight and whiteness of the zinc soap are the main points in favour of this method, which is said to yield good results.

Colouring.—The pulp, after passing through the various processes described, although apparently white, invariably presents a yellow tinge when converted into paper. To obviate this it is usual to "kill" the yellow tint by adding to the pulp small quantities of blue and pink colouring matters. The blue colours generally used are ultramarine, smalts, and various aniline blues, and the pinks are usually prepared from cochineal, either in a liquid form or as "lakes" (compounds of cochineal and alumina) or aniline dyes, the former being preferable, as it is not injuriously affected by the alum used in sizing. The ultramarine should be of good quality, otherwise it will become decomposed, and its colouring property destroyed by the action of the alum, but more especially so if the alum contains an excess of free acid. Smalts blue, which is a kind of coloured glass, is not affected by acids. In preparing the colouring matters for mixing with the pulp they must first be mixed with water, and the liquid should then be strained, to keep back any solid particles that may be present in the material. Aniline blues should be dissolved in hot water, or alcohol, and then diluted. Samples of the pulp are examined from time to time until the desired effect is produced, which the practised eye of the beaterman can readily determine.

Animal or Tub-sizing.—Another process of sizing, termed "animal-sizing," "tub-sizing," or "surface-sizing," is also adopted in the manufacture of certain classes of paper, and is either accomplished by hand or on the machine. The former method having been elsewhere described (p. 132) we will now describe the operation of sizing on the machine, to which the term tub-sizing is also applied. The size employed, which is prepared from what are called "glue pieces," or clippings of "limed" and unhaired skins of animals, requires to be as colourless as possible, in order that the colour of the paper may not be injuriously affected by it.

Preparation of Animal Size.—This operation is generally conducted at the mill, the materials from which the size is produced being the cuttings or parings of animal skins and hides, or *pelts*, which have undergone the processes of "liming" and unhairing preparatory to being tanned. The cuttings, or *pates*, commonly called "glue pieces," are first soaked in a mixture of lime and water, placed in large tubs for several days, after which they are put into a wooden cylinder, or drum, five or six feet in diameter, and about ten feet in length, which revolves upon a horizontal shaft, which, being hollow, admits the passage of water to the interior of the drum. The drum is perforated, and revolves in a large tank, while a continuous stream of water is allowed to pass through it, and the dirty water escapes through the perforations in the drum. When the cuttings are sufficiently cleansed in this way, they are transferred to an iron copper, furnished with a false bottom and steam-pipe, or a jacketed pan. The cuttings are next covered with water; steam is then turned on, and the liquid brought to a temperature below boiling point, or say, about 180° to 190° F., it being very important that the liquid should not actually boil. This operation is carefully kept up for twelve to sixteen hours, according to the nature of the cuttings, by which time all the material excepting any membranous or fatty matters that may be present, will have become dissolved and a solution of gelatine obtained. The liquor is then allowed to settle for a short time to allow fatty matters to rise to the surface and membranous substances to deposit, and the fatty matters must afterwards be carefully removed by skimming. The liquor should next be strained to separate any floating particles of a membranous character. Sometimes the gelatine solution is clarified by adding a small quantity of powdered lime, which is thoroughly mixed by stirring, after which it is allowed to rest. When it is found that the impurities and lime deposit too slowly, a little weak sulphuric acid is added, which, forming an insoluble sulphate of lime, the solid matters quickly subside, leaving the liquor quite clear. The solution is next filtered through felt, and is afterwards treated with a solution of alum, which at first causes the liquid to thicken and become nearly solid, but it becomes fluid again, however, on the addition of more alum solution. When this condition is finally attained, the liquid is ready for use in the process of sizing. The addition of the alum (which should not contain any free acid) to the gelatine greatly improves its sizing property, besides preserving it from decomposition. The treatment of the glue pieces for the purpose of obtaining gelatine solutions is fully described in the author's work on "Leather Manufacture," p. 401.*

American Method of Sizing.—Another method of preparing size, and which is adopted in America, is the following:—In large paper mills the size is generally prepared in a room devoted to the purpose, and is commonly situated near the machine. The finest grades of light hide and skin clippings are used for No. 1 letter papers, but less costly stock is employed for the lower grades of animal-sized papers.

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* "Art of Leather Manufacture." By Alexander Watt. Crosby Lockwood and Son, 1885.

machine-sizing, which is also called tub-sizing, the former being applied to papers of the finest quality. Papers that have been made by the machine, after being cut into sheets, are hand-sized, as described in the next chapter.

Machine-Sizing.—The lower-priced papers, to be machine-sized, are first partly dried over a few cylinders, after which the paper passes through a tank containing liquid size, from whence it passes between two rollers, which squeeze out the superfluous size; it is then wound on to a reel on which it remains some time to enable the size to thoroughly permeate the paper, after which it is wound on to another reel, and from thence it passes over a series of wooden drums or cylinders, each of which is furnished with a revolving fan; by this means the paper becomes dried slowly, whereby a more perfect sizing of the material is effected.

Double-Sized Paper.—This term is applied to paper which, after being sized in the engine in the usual way, is afterwards "surface sized," as it is called, with animal size in the manner described.

Respecting the drying of paper after it has been tub-sized there seems to be some difference of opinion as to whether it is best to hang it in a loft to dry or to dry it over the cylinders of a drying machine. Upon this point the New York *Paper Trade Journal* makes the following remarks:—"When the paper is passed through the size-tub, it is again wet; the fibres expand, and their hold on each other is relaxed. Now it must make a difference to the subsequent strength and quality of this paper whether it be hung up in a loft to dry or run over a drying machine. If it is hung in the loft no strain is put upon it and the fibres are at liberty to shrink, or slowly contract, in all directions; whereas if it is run over a drying machine, consisting of from 50 to 100 reels, the longitudinal strain prevents the fibres from shrinking and reassuming their normal position in that direction. Attempts have been made to obviate this defect by regulating the speed of each section of the machine in such a manner as to allow for the shrinking, but this only remedies the evil by preventing the paper from breaking as it travels over the machine. Everything else being equal, it would seem that loft-dried paper must be superior to that dried over the drying machine. Our home manufacturers endorse this view, inasmuch as they continue to prefer the system of loft-drying to the less expensive machine methods."

Mr. Wyatt's Remarks on Sizing.—Mr James W. Wyatt, in a paper on the "Art of Paper-making,"* makes the following observations on engine-sizing and animal-sizing which will be read with interest:—"Engine-sizing renders the paper fully as non-absorbent as animal size. The latter penetrates the sheets only slightly and forms a coating or skin on each surface, whereas the engine size surrounds each fibre and impregnates the whole mass. Surface-sizing, however, produces a stronger, firmer sheet, and is smoother for the pen to travel over; the manufacturer also gets the benefit in the price of the paper of the additional weight of the size, amounting to 7 per cent. on the average. On the other hand, as the animal size is mostly a skin on the surface, if the coating be broken anywhere by the use of a knife in scratching, the paper will only imperfectly resist ink in that place, a great disadvantage for account and office-books and ledgers. Engine-sized paper is much cheaper to produce than animal sized, and is therefore used principally for the lower qualities of writings and for almost all kinds of printings where firmness and smoothness is not so much a desideratum. Most tub-sized papers have a certain portion of engine size mixed with the pulp. This not only ensures the thorough sizing of the sheet, but also is a measure of economy in reducing the absorbing power of the paper for the animal size. Papers for ledgers and office-work are best given an extra proportion of engine size to ensure their ink-resisting properties, and they are also sized by hand in animal size and loft dried." The following rough estimate of the comparative cost in materials and wages of engine-sizing and animal-sizing paper may be of interest:

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* "Proceedings of the Society of Civil Engineers," vol. lxxix. p. 245.

Engine-sizing, per 20,000 lbs.:—

	£	s.	d.		d.
Materials . .	5	2	0		
Wages . . .	0	12	6		
Total . .	£5	14	6	Cost per lb. =	0·068

Animal-sizing, per 20,000 lbs.:—

	£	s.	d.
Materials . .	36	0	0
Wages . . .	4	10	0
Total . .	£40	10	0

CHAPTER XII.

MAKING PAPER BY HAND.

The Vat and Mould.—Making the Paper.—Sizing and Finishing.

UNDER the old system of making paper by hand, the rags were reduced to a fine state of division by a process of *retting*, or slow putrefaction. The rags were first washed in water, and then piled in heaps, in which condition they were allowed to remain until they became tender, that is, readily pulled asunder by the fingers. During the decomposition the rags not unfrequently became rotten in some portions of the heaps, thus involving considerable loss of fibre. The rags were next placed in a strong chest, in which iron-shod stamping rods were fitted, and these by their continued action gradually reduced them to a pulp. The stampers were eventually superseded by the beating-engine, the invention of a Dutchman, which received and still retains the name of the "Hollander." Other machines, as the duster, washing and breaking engines, and the beating engine,. have entirely taken the place of the older system, which required the work of forty pairs of stamps for twenty-four hours to produce one hundredweight of paper.

The Vat and Mould.—The pulp being prepared, is conveyed from the beaters to the working vat, where it is diluted with water. The vat is a wooden or stone vessel about 5 feet square and 4 feet deep, being somewhat wider at the top than at the bottom. A steam-pipe is supplied to the vat, so that the pulp and water may be heated to a convenient temperature for working, and an agitator is also furnished to keep the pulp and water uniformly mixed. The mould in which the pulp is raised from the vat to form a sheet of paper, consists of a wooden frame, neatly joined at the corners, with wooden bars running across, about 1½ inch apart, and flush with the top edge of the frame. Across these again, in the length of the frame, wires are laid, about fifteen or twenty in an inch, which are placed parallel to each other. A series of stronger wires are laid along the cross-bars, to which the other wires are fastened; these give to what is termed "laid" paper, the ribbed or "water-marked" lines noticeable in hand-made paper. Upon the mould is fitted a movable frame, called the *deckle* or *deckel*, which must fit very neatly or the edges of the paper will be rough. The mould and deckle form together a kind of shallow tray of wire. Sometimes the mould is divided by narrow ribs of wood, so that two or four sheets of paper may be made in one operation. Connected with the vat is a slanting board, called the *bridge*, with copper fillets attached lengthwise upon it, so that the mould may slide easily along the bridge.

Making the Paper.—When preparing for work, the vat-man stands on one side of the vat, and has on his left hand a smaller board, one end of which is fastened to the bridge, while the other rests on the side of the vat. An assistant, called the *coucher*, is at hand, whose duty it is to handle the frames or moulds containing the pulp after they have passed through the hands of the vat-man or maker. The latter now takes in his hand a mould, and lays it upon the deckle; he then dips the mould, with its deckle in its proper place, into the vat of agitated pulp, and lifts up as much of the pulp as will form a sheet of paper. This, as will be readily seen, requires the greatest dexterity, since the workman has nothing but his sense of feeling to guide him. It is said, however, that practice gives him such a nicety of feeling in this respect that he can make sheet after sheet of the largest-sized drawing papers with a difference in weight of not more than one or two grains in any two of them. Great skill is also required to hold the mould in a perfectly horizontal position, otherwise during the felting and settling of the pulp the sheet of paper would be thicker on one part than another. The mould being held lengthwise, that is, with the long parallel wires running from right to left hand, he gives the mould a gentle shake from his chest forward and back again, which is called the *fore-right shake;* this shake takes place across the wires, not in the direction of their length. He next gives a shake from right to left, and back again, the respective movements thus propelling the pulp in four directions. The vat-man now pushes the mould along the small board on his left, and removes the deckle, which he connects to another mould and proceeds to form another sheet of paper, and so on. The coucher, taking the first mould in hand, turns it upside down upon a piece of woollen felt-cloth, then removing the mould, he takes another piece of felt and lays it over the sheet and returns the mould by pushing it along the bridge to the vat-man, when he receives in return a second mould to be treated as before.

In the above way felts and paper are laid alternately until a pile of six or eight quires is produced, which is afterwards submitted to pressure in a very powerful press. When sufficiently compressed, the machine is relaxed, and the felts are then drawn out, on the opposite side, by an operative, called a *layer*, who places the felts one by one upon a board, and the sheets of paper upon another board. The coucher then uses the felts again for further operations. Two men and a boy only are employed in this part of the work. In the evening all the paper made during the day is put into another press, and subjected to moderate pressure to obliterate the felt marks and expel a further portion of the water. On the following day the paper is all separated, which is called *parting*, again pressed, and is then transferred to the drying-loft. The drying is effected by suspending the sheets of paper upon a series of ropes, attached to wooden supports; ropes of cow-hair are used for the purpose, as this material does not stain the paper.

Sizing and Finishing.—When the paper is dry, it is taken down and laid carefully in heaps ready for sizing, which is the next operation to which the paper is subjected. The preparation of the size from animal skins, etc., is described in Chapter XI. When preparing to size the paper, the workman takes several quires of the paper, and carefully spreads the sheets out in the liquid size, which is placed in a large tub, taking care that each sheet is uniformly moistened before introducing the next. The superfluous size is afterwards pressed out, and the paper then "parted" into separate sheets, which are again subjected to pressure, and finally transferred to the drying-room, where they are allowed to dry slowly. When dry, the paper is conveyed to the finishing-house, to be again pressed and looked over by women, who, being furnished with small knives, pick out knots and other imperfections and separate the perfect from the imperfect sheets. The paper is now again pressed, and then handed to the finisher, to be counted into reams and packed, the reams being afterwards pressed and finally tied up and conveyed to the warehouse for sale. When the paper is required to be hot-pressed, this is done by placing each sheet of paper alternately between two smoothed sheets of pasteboard, and between each group of fifty pasteboards is placed a hot plate of iron, and the pile then submitted to heavy pressure, whereby the surface of writing paper acquires a fine, smooth surface.

CHAPTER XIII.

MAKING PAPER BY MACHINERY.

The Fourdrinier Machine.—Bertrams' Large Paper Machine.—Stuff Chests.—Strainers.—Revolving Strainer and Knotter.—Self-cleansing Strainer.—Roeckner's Pulp Strainers.—The Machine Wire and its Accessories.—Conical Pulp Saver.—The Dandy Roll.—Water Marking.—De la Rue's Improvements in Water-marks.—Suction Boxes.—Couch Rolls.—Press Rolls.—Drying Cylinders.--Smoothing Rolls.—Single Cylinder Machine.

The Fourdrinier Machine.—It is just ninety years since Louis Robert, a Frenchman, devised a machine for making a continuous web of paper on an endless wire-cloth, to which rotary motion was applied, thus producing a sheet of paper of indefinite length. The idea was subsequently improved upon by Messrs. Fourdrinier, who adopted and improved upon M. Robert's machine, and with the valuable aid of Mr. Bryan Donkin, a young and gifted machinist, in the employ of Mr. Hall, engineer, of Dartford, constructed a self-acting machine, or working model, in 1803, which, from its effectiveness and general excellency of workmanship, created at the time a profound sensation. This machine was erected at Frogmore, Hertfordshire; and in 1804 a second machine was made and put up at Two-Waters, Herts, which was completely successful, and the manufacture of continuous paper became one of the most useful and important inventions of the age. From that period the "Fourdrinier," with some important improvements introduced by Mr. Donkin, gradually, but surely, became established as an absolutely indispensable machine in every paper-mill all over the world. Although the machine has been still further improved from time to time, those of recent construction differ but little in principle from the original machine. An illustration of the machine is shown in Fig. 25, the detailed parts of which are expressed on the engraving.

Bertrams' Large Paper Machine.—The principal aim in the construction of the paper-making machine has been to imitate, and in some particulars to improve, the operations involved in the art of making paper by hand, but apart from the greater width and length of paper which can be produced by the machine, the increased rapidity of its powers of production are so great that one machine can turn out as much paper in three minutes as could be accomplished by the older system in as many weeks. The drawing represents the modern paper-machine as manufactured by Bertrams, Limited, who supplied one of these machines to Mr. Edward Lloyd, for the *Daily Chronicle* Mill, at Sittingbourne, which runs a wire 40 feet long by 126 inches wide, this being, we believe, the largest and widest paper-machine in the world. It is provided with 20 cylinders, chilled calenders, double-drum reeling motion, with slitting appliance for preparing webs to go direct to the printer's office without the assistance of a re-reeling machine, and is driven by a pair of coupled condensing steam-engines. On our recent visit to Mr. Lloyd's mill we were much struck with the excellent working of this splendid machine.

In the illustration, as will be seen, there are two sets of drying cylinders, while small cylinders, or felt drying-rolls, from 16 to 24 inches in diameter, are introduced to the felts of the cylinders, before the smoothing-rolls, which discharge the moisture with which the felts are impregnated from the damp paper, whereby a considerable saving in felts is effected. Messrs. Bertram state that the highest speed yet attained has been by their own machinery, and is 270 feet of paper per minute.

The progress of the pulp after it leaves the beating-engines for conversion into paper may be described as follows:—The valve at the bottom of the beating-engine

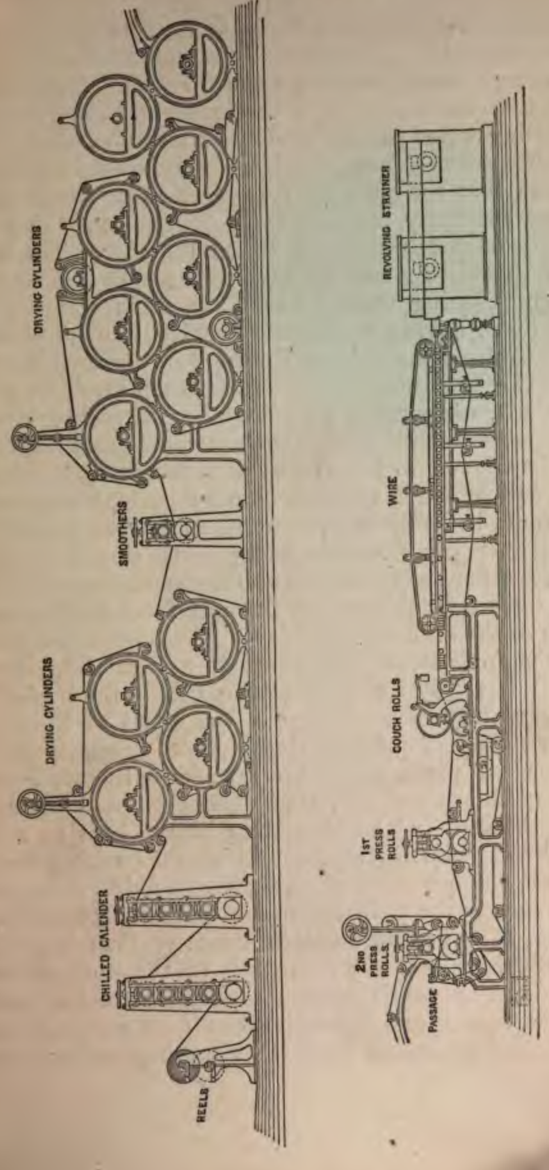
REELS
CHILLED CALENDER
DRYING CYLINDERS
SMOOTHERS
DRYING CYLINDERS
PASSAGE
2ND PRESS ROLLS
1ST PRESS ROLLS
COUCH ROLLS
WIRE
REVOLVING STRAINER

Fig. 25.

is opened, when the pulp flows through a pipe into the stuff-chests, which are generally situated below the level of the engines. The beaters are then rinsed with clean water to remove any pulp that may still cling to them, the rinsing water passing also into the stuff-chests.

Stuff-chests.—These are large vessels of a cylindrical form, so that the pulp may have no corners to lodge in, and are generally made of wood, though sometimes they are made of cast-iron plates bolted together. The chests are of various dimensions, according to the requirements of the mill, being usually about 12 feet in diameter and 6 feet deep, having a capacity for 1,000 to 1,200 lbs. of stuff. To keep the pulp well mixed in the stuff-chest, of which two are usually employed for each machine, a vertical shaft, carrying two horizontal arms, each extending nearly across the interior of the chest, are provided, which are only allowed to revolve at a moderate speed, that is, about two or three revolutions per minute, otherwise the pulp would be liable to work up into knots, and thus form a defective paper. Motion being given to the shaft, the rotating arms keep the pulp and water uniformly mixed, at the same time preventing the pulp from sinking to the bottom of the stuff-chest.

The pulp is next transferred to a regulating box, or "supply box," by means of a pump called the *stuff-pump*. The regulating-box, which has the effect of keeping a regular supply of pulp in the machine, is provided with two overflow pipes, which carry back to the stuff-chests any superfluous pulp that may have entered them, by which the stuff in the regulating-box is kept at a uniform level, while the machine is supplied with a regular and uniform quantity of the diluted pulp. The stuff-pump conveys the pulp through a valve in the bottom of the regulating-box in a greater quantity than is actually required, the superfluity returning to the stuff-chests by the overflow pipes; thus the supply-box, being always kept full, furnishes a regular and uniform supply of pulp to the sand-tables, or sand-traps as they are sometimes called. *Sand-tables* are large wooden troughs, varying in size at different mills, but Mr. Dunbar gives the following proportions for a first-class sand-trap; namely, 14 feet long by 8 feet wide, and 8 inches deep. The bottom of the trap is covered with felt, sometimes old first-press felt being used, and is divided into several compartments by thin bars of lead or iron, or strips of wood, which keep the felt in position, and also retain any particles of sand or other heavy solid matter that may be accidentally present in the pulp. For the purpose of diluting the pulp for the machine, there is, attached to the inlet of the sand-traps, a box with two supply-taps, one for the delivery of pulp, and the other for water; and these being turned on, the pulp and water flow over the sand-traps, and the diluted pulp then falls into the strainers, which, while allowing the fine pulp to pass freely, keep back all lumps of twisted fibre, and particles of unboiled fibre, which latter, if not removed, would appear as specks on the surface of the finished paper.

The Strainers are formed of brass or bronze plates, in which are cut a very large number of narrow slits, which gradually widen downward, so as to prevent the pulp from lodging. Each plate has about 510 slits, and several plates, connected together by bolts, constitutes the complete strainer. When in use, the strainer receives a jogging motion, which is communicated to it by means of small ratchet wheels keyed on shafts passing beneath the machine; this causes the fibres to pass more freely through the slits. There are many different forms of strainers, which have been the subject of numerous patents. It will be sufficient, however, to give one or two examples of improved strainers which have been more recently adopted by manufacturers.

Revolving Strainer and Knotter.—The revolving strainer, which was invented by the late senior partner in the firm of Messrs. G. and W. Bertram (now Bertrams, Limited), has since been extensively adopted, and the present firm have introduced a patent knotter in conjunction with the apparatus, the complete arrangement of which is shown in Fig. 26. The standard size for these revolving strainers is 7 feet long by $18\frac{3}{8}$ inches wide on each side of the four surfaces. The vats are of cast iron, and

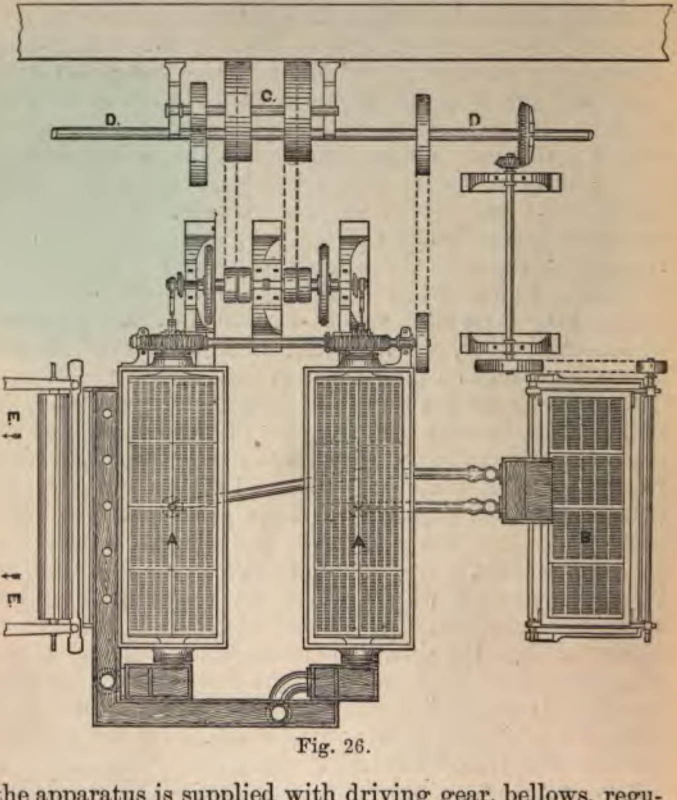

Fig. 26.

the apparatus is supplied with driving gear, bellows, regulating boxes and spouts, as necessary. The firm also supply these strainers with White's patent discs, and Annandale and Watson's arrangement. A A are two revolving strainers, as applied to the paper-machine, showing gearing for strainers and bellows. B is the patent knotter as used for two strainers. C is the counter-shaft overhead.

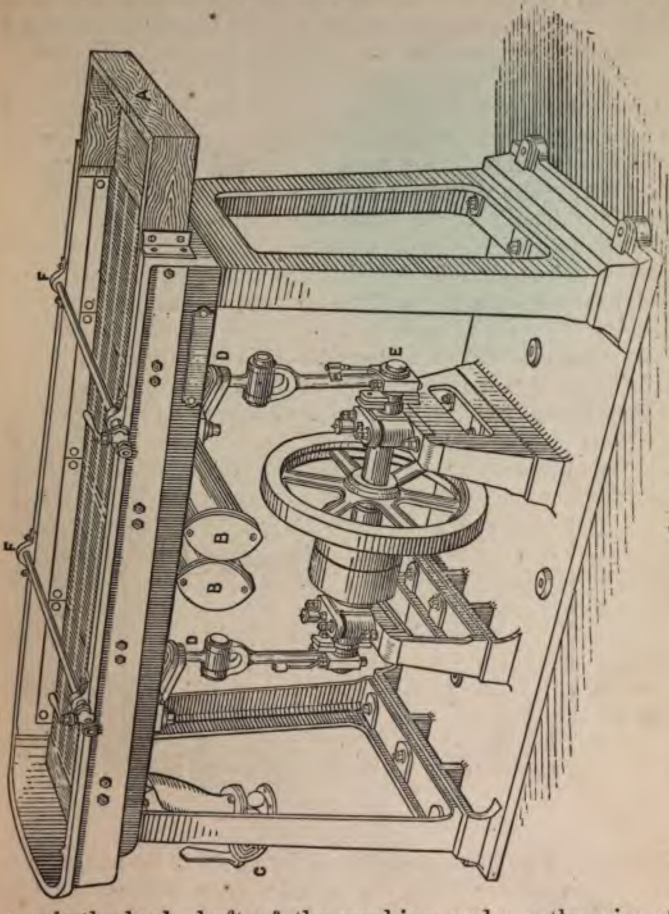

Fig. 27.

D D is the back shaft of the machine, and E E the wire of the paper-machine.

Self-cleansing Strainer.—The same firm also introduced this form of strainer, an illustration of which is given in Fig. 27. The action of the strainer is described as follows:—

The pulp flows on to the strainer at A, and passes away through the pipes B B. At C is a valve for the discharge of waste pulp. The strainer plates have an inclination of about 1 inch in the direction of their length, and in those which are nearest to A, where the pulp enters, the slits are wider, the knots being pushed forward by the energy of the flow. The vacuum pumps, D D, are worked from the shaft E. The tubes F F are for supplying water to the plates, by which the coarser particles of the pulp are pushed forward, and the slits are thus kept clean. The strainer will pass from 18 to 20 tons of the finest paper per week.

Roeckner's Pulp Strainers.—This invention consists in constructing boxes, with one or both ends open, forming the strainers, fixed, or to slide in or out, so as to be readily

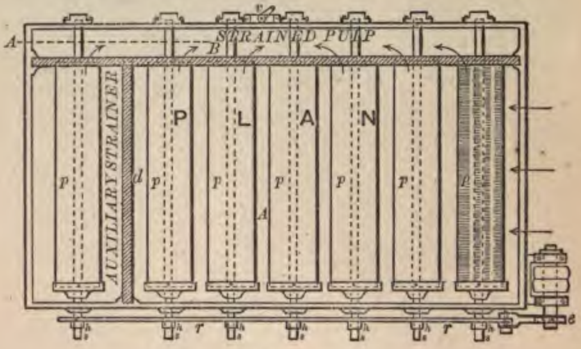

Fig. 28.

cleaned. One or more fans are fitted in these boxes, and are put in motion from the outside, so as to cause what is called "suction" through the strainers. One or a number of such boxes are fixed into a vat, the open ends discharging the pulp which has passed through the strainers to the paper-machine, and can be so arranged that all the fans are worked on one shaft. The vat may be divided into compartments, so that the stuff flows from one to the other. Instead of boxes, the strainers may be formed of tubes, in which suitable slits or perforations have been provided. The tubes will be perfectly closed at one end, and the strained pulp, after passing through them, will be delivered to the paper-machine from their open ends, which may fit into a ring, so that when cleaning is required they may be easily lifted out or in. The suction is provided inside these tubes by the fans, which are oscillated by suitable gear from the outside of the vat. The strainers may, instead of being stationary, be attached to the fans and oscillate with them, in which case the open ends would have to be attached to the vat by an indiarubber or cloth ring, or the strainers may oscillate whilst the fans are stationary. Any number of these strainers may be fixed into vats, disposed vertically or otherwise. In the vat A, Fig. 28, which receives the pulp to be strained, are several tubes, *p p p*, with one end open, having slits in them similar to strainer plates. Inside of these are two, three, or more plates, *f f f*, Fig. 29, running the full length of the tube fixed to the shafts, *s s s*, and to the sides of the tubes, which serve as fans, besides giving strength to the tubes. The shafts *s s s* are carried in bearings at each end, and have each one end projecting through, upon which are keyed levers, *h h h*, which, being connected to a rod *r*, worked by an eccentric, *e*, at the end, gives an oscillating motion to the tubes and fans. Any number of tubes may

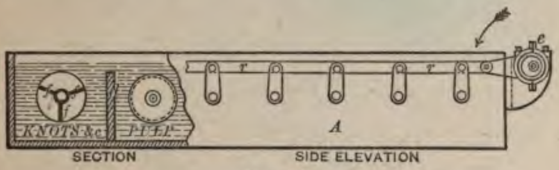

Fig. 29.

be in the vat, and may either work separately or divided. With several tubes it is preferable to have them arranged as shown in the drawing by division plate *d*, so that the accumulated "knots," &c., may flow finally into the end compartment (which will form an auxiliary strainer), and may be mixed with more water, so that the fine pulp still contained in the stuff can flow away through the slits and the knots, &c., be taken out when necessary. The tubes should be placed so far apart that a workman can get his hand between. The closed ends work free in the stuff, while the open ends run through indiarubber sheet or other material, fitted so well to the tube that the fibre can only get through the slits of the tube to flow on to the paper-machine through the channel at side by the sluice *v*. The arrows indicate the direction of the flow of pulp.

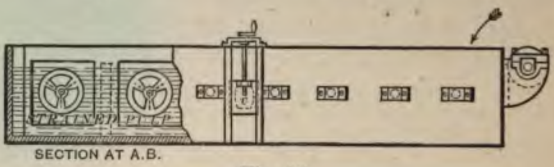

Fig. 30.

Mr. Dunbar says, "the straining power necessary to pass and clean pulp in an efficient manner for 25 tons of finished paper per week is two revolving strainers, consisting of four rows of plates, or 7 feet by 18 inches of straining surface on each of the four sides, the plates being cut No. 2½ Watson's gauge."

After passing through the strainers the pulp should be absolutely free from knots or objectionable particles of any kind, and in a proper condition for conversion into paper.

The Machine Wire and its Accessories.—On leaving the strainers the pulp passes into a vat, in which is a horizontal agitator, which causes the pulp and water to become well mixed, and ready to flow on to the endless wire-cloth of the machine. The wire-cloth is made of exceedingly fine wire, the meshes ranging from 60 threads and upwards to the inch, there being sometimes as many as 1,900 holes per square inch, but the meshes usually employed run from 2,000 to 6,000 per square inch. The ends of the cloth are united by being sewn with very fine wire. The width of the wire-cloth varies considerably, the greatest width being, we believe, that supplied for the large machine at Mr. Edward Lloyd's mill at Sittingbourne, which is 126 inches. The length of the wire-cloth is generally from 35 to 40 feet, the latter being considered preferable. Beneath the wire is placed a shallow box called the "save-all," which receives the water as it flows through the wire cloth from the pulp. In order to effect a further saving of pulp which escapes through the meshes of the wire-cloth, a machine called a "pulp-saver" is used at some mills, through which the backwater, as it leaves the box or save-all referred to, is passed.

The wire-cloth is supported by a series of brass tube rolls, which are so placed as to render the layer of pulp on the wire absolutely uniform, by which a regular thickness of the finished paper is ensured. The wire is attached to a malleable iron frame, having a sole-plate of cast iron, and carries a brass or copper breast-roll, 18 inches in diameter, a guide-roll 7 inches in diameter, and four brass or copper rolls 5 inches in diameter under the wire, with shafts extending through the rolls, and furnished with brass bushes and brackets, and a self-acting guide upon the 7-inch guide-roll. The tube-rolls or "carrying tubes" are carried upon brass bearings. Attached to the sole-plate of the wire framing are three cast-iron stands on each side for supporting the save-all beneath the wire. To regulate the width of the paper there is on the top of the wire a set of brass "deckles," carried on a brass frame passing over the first suction box, of which there are two, and supported on the wire frame by iron studs fixed in the frame. At each end of the deckle-frame is a pulley for carrying the deckle-strap, with three similar pulleys for expanding it. The deckle-frame is furnished with two endless straps of india-rubber, these straps keeping the pulp to the width required for forming ledges at the sides of the web.

The Conical Pulp-saver, which is shown in Fig. 31, was invented by the late Mr. George Bertram and Mr. Paisley, and is manufactured by Bertrams, Limited. Its use is to extract fibres from the washing water before going into the river or otherwise. For the water from the drum-washer, washing and beating engines, and for the water from the paper-making machine, save-all, &c., it has proved itself of great utility. It is simple in construction,. small in cost, takes up little room, and is easily repaired. When placed to receive the washings from the beaters or paper-machine, the pulp saved, if kept clean, can always be re-used. A is a conical drum which is covered with wire-cloth, and it is made to revolve slowly by suitable gearing. The water enters by the pipe B, which is perforated, as shown, and passes through the meshes of the gauze, while the pulp gradually finds its way to the wider end of the drum, where it escapes into the box C, and can be conveyed again to the beating-engines.

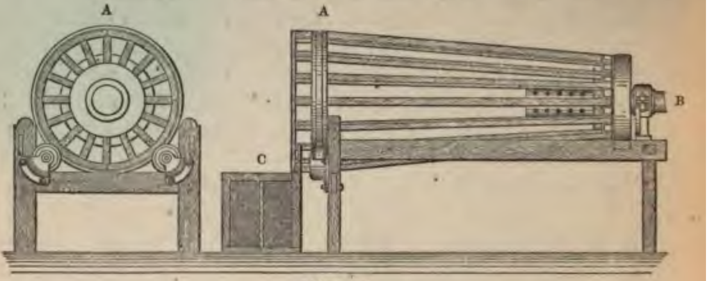

Fig. 31.

The Dandy-roll.—When it is required to produce a design or name, termed a *water-mark*, upon the paper, this is done by means of a roll called the *dandy-roll*, which consists of a skeleton roll covered with wire-cloth, upon which the design is worked by means of very fine wire. If the paper is required to be alike on both sides, without any specific pattern or name upon it, the roll is simply covered with wire-cloth, the impressions from which upon the moist pulp correspond with those of the machine-wire on the under surface. By this means paper known as "wove" paper is produced. A dandy-roll of this character is shown in Fig. 32. "Laid" paper, as it is termed, is distinguished by a dandy-roll having a series of equidistant transverse wires on the upper surface of the wire cylinder, as shown in Fig. 33, the effect of which is to produce parallel lines on the paper, caused by the pulp being thinner where the moist paper is impressed by the raised wires, which renders the lines more transparent than the rest of the paper. The dandy-roll, which is usually about 7 inches in diameter, corresponds in length

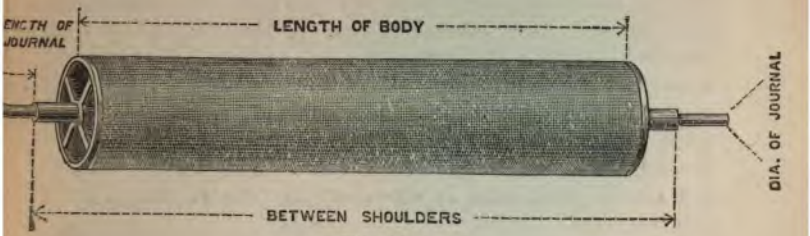

Fig. 32.

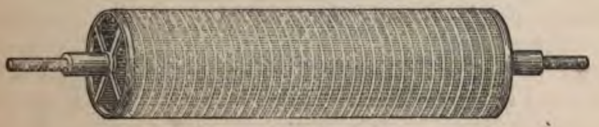

Fig. 33.

to the width of wire on which it rests, and is placed over the wire-cloth between the suction-boxes. The journals of the roll turn in slits in two vertical stands, one behind the machine frame and the other in front of it. The roll, however, rests with its whole weight on the wire, and revolves by the progressive motion of the wire. The stands which support the roll prevent it from being influenced by the lateral motion of the wire. By thus running over the surface of the pulp when the wire is in motion, this roll presses out a considerable quantity of water, at the same time rendering the paper closer and finer in texture. Dandy-rolls of various lengths, and bearing different designs or patterns, are kept at the paper-mills, and great care is exercised to preserve them from injury.

Water-Marking.—Dr. Ure describes the following processes for producing a design for a line water-mark:—1. The design is engraved on some yielding surface in the same way as on a copper-plate, and afterwards, by immersing the plate in a solution of copper sulphate, and producing an electrotype in the usual way, by which all the interstices become so filled up as to give a casting of pure copper. This casting, on being removed from the sulphate bath, is ready for attaching to the wire gauze of the dandy-roll. 2. The design is first engraved on a steel die, the parts required to give the greatest effect being cut deepest; the die, after being hardened, is forced by a steam hammer into some yielding material, such as copper, and all of this metal which remains above the plain surface of the steel is subsequently removed by suitable means; the portion representing the design being left untouched would then be attached to the wire-gauze as before. Light and shade can be communicated to the mark by a modification of the above process, for which purpose an electrotype of the raised surface of a design is first taken, and afterwards a second electrotype from this latter, which consequently will be identical with the original surface. These two are then mounted on lead or gutta-percha, and employed as dies to give impression to fine copper-wire gauze, which is then employed as a mould. Thus absolute uniformity, such as could not be attained by the old system of stitching wires together, is now attained in bank-notes by the adoption of the above method. It may be mentioned that when the moulds were formed by stitching the fine wires together to form a design, no less than 1,056 wires, with 67,584 twists, and involving some hundreds of thousands of stitches, were required to form a pair of £5 note moulds, and it was obviously impossible that the designs should remain absolutely identical.

Sometimes water-marks are produced by depressing the surface of the dandy-roll in the form of a design, which causes the paper to be thicker where the design is than in the rest of the sheet of paper. This modification was invented by Dr. De la Rue.

De La Rue's Improvements in Water-marks.—By one method, patented in 1869, dandy-rolls, having a surface of embossed wire-gauze, are used; the indentations in the gauze are inwards, causing a thickening of the paper where they are brought in contact with it. These thickenings correspond in form to the configuration of the design or water-mark. The inventor has also affixed wire to the surface of such dandy-rolls so as to form projections, in order to thin the paper where the projections come in contact with it, by which means light lines are obtained in the water-mark, strengthening the effect of the thickened opaque design.

By another patent, dated May, 1884, No. 8348, the inventor forms the surface of the dandy-roll of wire-gauze embossed in such a manner that parts of the surface of the gauze, corresponding to the configuration of the design of the water-mark, are raised, and project out from the general surface, and other parts corresponding to the line shading of the design are de-pressed below the level of the general surface. The accompanying drawing, Fig. 34, shows diagrammatically, and greatly enlarged, a section of a portion of the surface of a dandy-roll made in accordance with this invention. *a* represents the section of a ridge or projection raised on the surface of the gauze; *b* represents the section of a groove or depression in the wire-gauze, which, with other similar grooves, serves to produce an opaque shading to the design. *c* is an auxiliary ridge or projection, serving to define the shading line, and to intensify it by driving the pulp into the groove or depression *b*. Further effects may be obtained by attaching wires to the dandy-roll, either in the usual way, where the surface is unembossed, or upon the raised parts *a*, which give the configuration to the water-mark. In place of forming the ridges or projections *a*, which produce the configuration of the water-mark, by raising portions of the wire-gauze above the general surface, they may be formed by sewing on suitably shaped slips of wire-gauze, or of sheet metal perforated all over with fine holes, on to the surface of the gauze which is embossed with the grooves *b*, but it is much to be preferred that both the ridges *a* and the grooves *b* should be produced by embossing the gauze. Water-marks may also be produced by placing sheets of finished paper in contact with plates of copper or zinc, bearing a design in relief, and submitting them to heavy pressure.

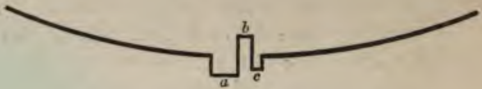

Fig. 34.

Suction-Boxes.—These boxes, which are fitted under the wire, are made of wood, and are open at the top, the edges being lined with vulcanite. The ends of the boxes are movable, so that they may be adjusted to suit the width of the paper required; they are also provided with air-cocks for regulating the vacuum, which is obtained by means of two sets of vacuum pumps, having three 6-inch barrels to each set: a vacuum pump of this form is shown in Fig. 35. As the wire travels over these boxes, the action of the pumps draws the wire upon them with sufficient pressure to render them air-tight; by this means a large portion of the water which the pulp still retains at this point becomes extracted, thereby giving to it such a degree of consistency that it can stand the pressure of the couch-rolls without injury. The back-water extracted by the suction-boxes, as also that collected in the save-all, is added to a fresh supply of pulp before it flows on to the sand-tables.

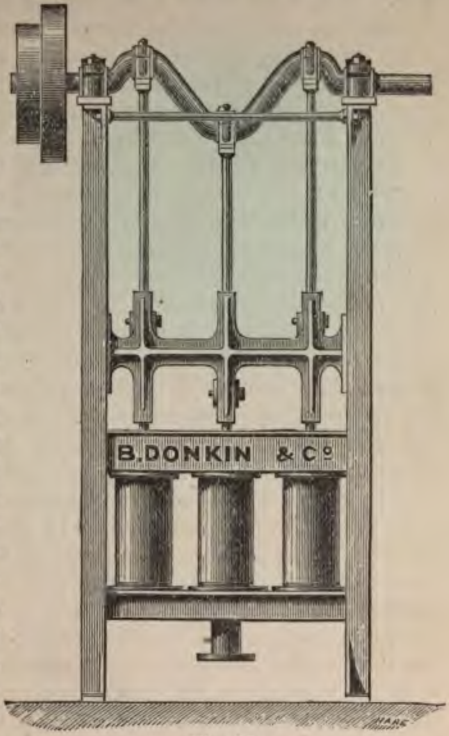

Fig. 35.

Couch-Rolls.—At the extreme end of the wire-cloth from the breast-roll, and inside the wire, is the under couch-roll, from which the wire receives its motion. This roll, which is of brass, is usually about 14 inches in diameter, is carried upon a cast-iron framing with brass bearings, and is ground to a working joint with the top roll, which is also of brass, and 20 inches in diameter. Both these rolls are covered with a seamless coating of woollen felt. The upper roll rests upon the lower one, and the wire-cloth, and the web of paper upon it, pass between the rolls, receiving gentle pressure, by which the paper becomes deprived of more water, rendering it still more compact. It is at this stage that the web of paper leaves the wire-cloth, and passes on to a continuously revolving and endless web of woollen felt, termed the "wet felt," from the moist condition of the paper. This felt, which is carried on wooden rollers, is about 20 feet long, and is manufactured with considerable care.

The Press-Rolls.—The paper now passes on to the *first press-rolls,* which deprive it of a still further quantity of water, and put it in a condition to bear gentle handling without injury. The upper roll is fitted with a contrivance termed the "doctor," which keeps the roll clean by removing fragments of paper that may have become attached to it. The doctor is furnished with a knife which passes along the entire length of the roll, pressing against it from end to end. These rolls are generally of iron, jacketed with brass, the under one being 14 inches in diameter, and the top roll 16 inches. Sometimes this roll is made of fine-grained cast-iron. When the roll is of iron the doctor blade is steel; but when this roll is brass the knife is of the same material. The under surface of the paper, which has been in contact with the felt, and necessarily being in a moist condition, receives more or less an impression from the felt over which it travelled, while the upper surface, on the other hand, will have been rendered smooth by the pressure of the top roll of the first press. To modify this, and to render both surfaces of the paper as nearly uniform as possible, the paper passes through another set of rolls, termed the *second press-rolls,* in which the paper becomes reversed, which is effected by causing it to enter at the back of the rolls, which rotate in a reverse direction to those of the first press, by which the under or wire side of the paper comes in contact with the top roll of the press. By this arrangement the underside of the paper is rendered equally smooth with the upper surface. The second set of press-rolls is provided with an endless felt of its own, which is usually both stronger and thicker than that used in connection with the first press-rolls. In some mills each set of press-rolls is provided with a doctor, to prevent the web of paper from adhering to the metal. Sometimes the doctor knives are made from vulcanite, a material which would seem specially suited for a purpose of this kind. From this point the paper passes to the first set of drying cylinders.

The Drying Cylinders.—The invention of the steam drying cylinder is due to Mr. T. B. Crompton, who, in the year 1821, obtained a patent for this useful addition to the paper-machine. Since that period, however, the system of drying the paper by steam-heat has been brought to a high state of perfection; not only this, but the number of cylinders has gradually increased, while the heat to which they are raised has proportionately decreased, and as a consequence the size, which is injuriously affected by rapid drying, is gradually deprived of its moisture, and thus renders the paper closer and stronger, while at the same time a very rapid speed can be maintained. The drying cylinders in the machine shown in the engraving are 4 feet in diameter and 12 in number, being arranged in two groups of 8 and 4 cylinders respectively, and in the aggregate present a very large drying surface, it being very important that the operation should be effected gradually, more especially at its earlier stages. There is a passage between the second press-roll and the cylinders, through which the machinemen can pass from one side of the machine to the other. The first two or three of the first section of cylinders are only moderately heated, and having no felt on them, allow the moisture from the paper to escape freely. The next five cylinders, however, are provided with felts, which press the paper against the heated surfaces, by which it becomes smooth and flattened, thus putting it into a proper condition for passing between the *smoothing-rolls*. The cylinders are heated by steam, and are generally of decreasing diameter, to allow for the shrinking of the paper during the drying.

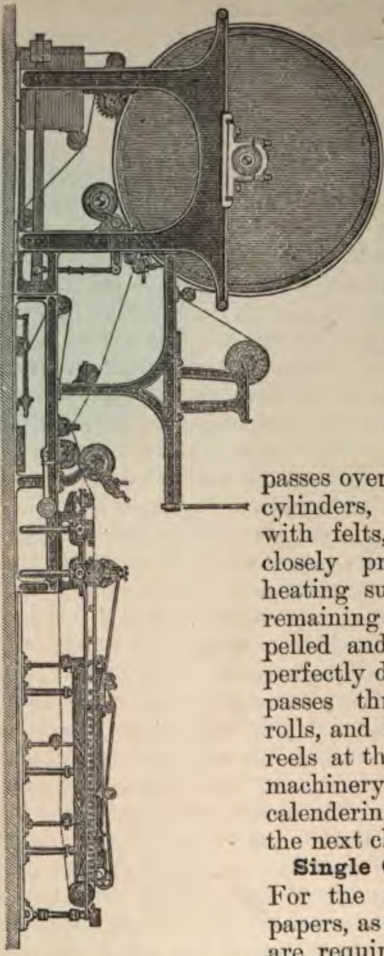

Fig. 36.

Smoothing-Rolls.—These consist of highly polished cast-iron rolls, heated by steam. The paper being in a somewhat moist condition when it passes through these rolls, they have the effect of producing a fine smooth surface.

The paper next passes over the last four drying cylinders, all being provided with felts, to keep the paper closely pressed against their heating surfaces, by which the remaining moisture becomes expelled and the paper rendered perfectly dry. The paper now passes through the calender rolls, and is then wound on to reels at the extreme end of the machinery. The operation of calendering will be treated in the next chapter.

Single Cylinder Machine.—For the manufacture of thin papers, as also for papers which are required to be glazed on one side only, a single cylinder machine, called the Yankee machine, has been introduced, a representation of which is shown in Fig. 36. It is constructed on the same principle as the larger Fourdrinier machine up to the couching-rolls, when the paper leaves the wire-cloth and passes on to an endless felt running round the top couch-roll, and passes from thence to a large drying cylinder, which is about 10 feet in diameter and heated by steam, the surface of which is highly polished, giving to the surface of the paper in contact with it a high gloss. There is attached to the machine an arrangement for washing the felt for the purpose of cooling and opening it out after passing through a cold press-roll and the hot drying cylinder. This machine, as manufactured by Messrs. Bentley and Jackson, for cap, skip, and thin papers, consists of a rocking frame, and wrought-iron side bars, fitted with brass bearings, the necessary brass and copper tube-rolls, couch-rolls, with driving shaft, stands and pulley; self-acting wire guide, brass deckle sides and pulleys, brass slice, vacuum boxes, pipes and cocks; wet felt frame, with the necessary water pipes and cocks, and carriages to carry the couch-rolls and felt-rolls; the necessary wet felt-rolls and a felt washing apparatus; one bottom press-roll carried by brass steps, and fitted with compound levers and weight; one large cast-iron drying cylinder about 10 feet in diameter, and fitted with a central shaft, steam admission and water delivery nozzles, two water lifters and pipes, a manhole and vacuum valve, a large spur driving wheel, spur pinion, driving shaft and pulley; massive cast-iron framework, with pedestals to carry the cylinder; traversing steel doctor and frames; copper leading roll and carriages, a pair of reeling stands fitted with brass steps, friction pulleys and plates, regulating screws, etc.; a wooden platform and iron guard rail, all carried by strong cast-iron framing; the necessary pulp and backwater pumps, shake, knotter, stuff chests, service cistern, pipes and valves, shafting, pedestals, change wheels, pulleys, &c. These machines can be obtained of any desired width.

CHAPTER XIV.

CALENDERING, CUTTING, AND FINISHING.

Web-glazing.—Glazing Calender.—Damping-Rolls.—Finishing.—Plate Glazing.—Donkin's Glazing Press.—Mr. Wyatt on American Super-calendering.—Mr. Arnot on Finishing.—Cutting —Revolving Knife Cutter.—Bertrams' Single-sheet Cutter.—Packing the Finished Paper.—Sizes of Paper.

To impart a higher gloss, or, as it is technically termed "glaze," to paper after it leaves the machine, it has to be subjected to further calendering, which is accomplished either in the web, or in sheets, according to the quality of the paper.

Web-Glazing.—*Glazing Calender.*—When paper has to be glazed in the web, it is passed between a series of rolls, which are constructed upon several different systems. In one form of this machine the rolls are alternately of finely polished iron, and compressed paper, or cotton, the iron rolls being bored hollow to admit of their being connected to steam pipes, for heating them when necessary. In this machine there are eight rolls, the centre pair being both paper rolls, which have an effect equivalent to reversing the paper, by which both sides are made alike. Another form of glazing calender, of American origin, but which has been improved upon by our own engineers, consists of a stack of rolls made from chilled iron, the surfaces of which are ground and finished with exquisite precision upon a system adopted in America. A representation of this calender as manufactured by Messrs. Bentley and Jackson is given in Fig. 37. Such rolls as require heating are bored through, and their ends fitted with brass junctions and cocks, to regulate the admission of steam.

The standards are of cast iron, planed and fitted with phosphor bronze bearings; the bearings to carry the top roll of the stack are furnished with wrought-iron screws and hand wheels, and wrought-iron lifting links can be attached to raise one or more of the rolls, according to the finish required on the paper. Compound levers are also supplied, to regulate and adjust the pressure on the ends of the rolls.

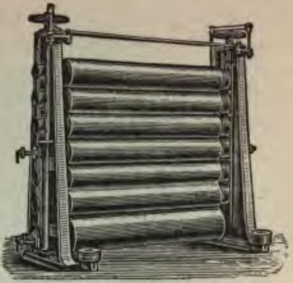

Fig. 37.

Damping Rolls.—An important improvement in connection with the calendering of paper was introduced by Messrs. G. and W. Bertram a few years since, by which a higher finish is given to the paper than had previously been attainable. This consists of a damping apparatus A (Fig. 38) which is placed between the last drying cylinders B of the machine and the glazing calenders C. The damping-rolls consist of

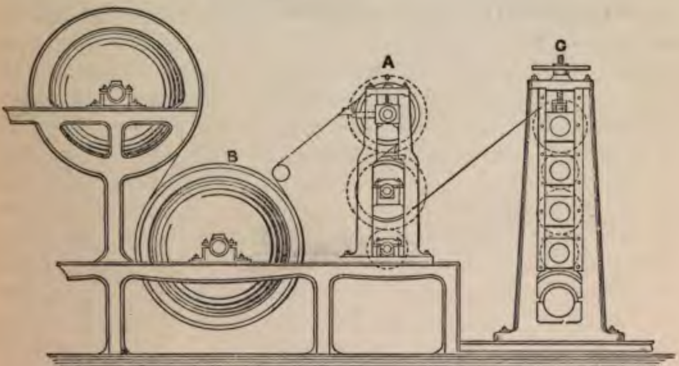

Fig. 38.

two brass or copper rolls, about 14 inches in diameter, through which a constant stream of cold water is passed, while a line of steam jets, issued from finely-perforated pipes, plays over the face of the rolls. The cold water within the rolls condenses the steam, thereby imparting a uniform moisture to the under surface of the paper, which enables it to take a better surface when passing through the glazing rolls. The steam-pipes can be regulated so as to give any amount of dampness required by adjusting the steam cocks accordingly. By reference to the engraving, it will be observed from the disposition of the rolls that the web of paper is reversed, thus equalising the moisture on both sides, by which the paper-maker is enabled to produce an evenly-finished paper.

The chilled-iron glazing-rolls, as originally introduced, were fitted up in stacks of seven, and sometimes as many as nine rolls, but it was found in practice that so large a number of rolls gave unsatisfactory results; the heavy pressure, acting on the paper immediately after leaving the drying cylinders, had the effect of "crushing" the paper, giving it a thin feel. It is now considered preferable to use calenders having not more than four, or at most five rolls. An arrangement of this description, manufactured by Bertrams, is represented in Fig. 39. The system recommended by Mr. Dunbar is to employ three sets of

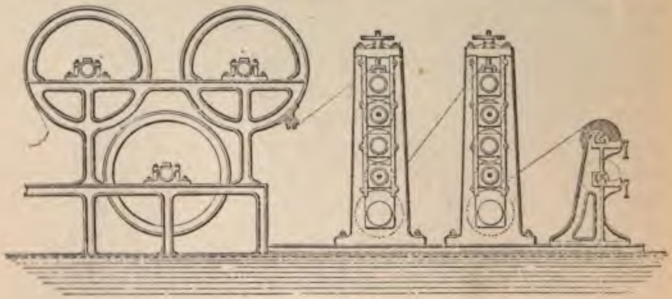

Fig. 39.

rolls, disposed as follows:—"First, a set of three rolls; second, a set to consist of four rolls, and a stack of five to give the finishing or dry surface. With this arrangement of calenders, and the assistance of the damping apparatus, any desired surface can be got by varying and regulating the drying of the paper, which any careful machine-man can do with ordinary attention."

Finishing.—To give a still higher finish to the paper, it is subjected to what is termed "friction-glazing," which consists in passing it through a stack of rolls, formed alternately of small iron rolls and larger paper ones, the iron rolls revolving at a much higher speed than the paper-rolls. The effect of this final glazing operation gives the paper a very fine surface.

Plate-Glazing.—*Donkin's Glazing Press.*—This term, which is also called "super-calendering," is applied to a method of glazing hand-made paper, and is also adopted for the better qualities of machine-made paper. It consists in placing sheets of paper between highly polished plates of either copper or zinc, the latter being more generally used. The metal plates, with the sheets of paper placed alternately between them, are made up into packs or "handfuls" (the operation being usually performed by women), and these are passed between two powerful rolls, giving a pressure of from twenty to thirty tons, and each pack, consisting of about forty plates and as many sheets, is passed through the rolls several times, the pressure being regulated by means of screws or levers and weights acting on the ends of the top roll. A machine for glazing paper in packs, manufactured by Messrs. Bryan Donkin and Co., is shown in Fig. 40. Some descriptions of paper, as "antique" and "old style," for example, are surfaced with good cardboard instead of copper or zinc plates. As soon as the handful has passed through the rollers, the motion of the machine is reversed, by which means the pack is made to pass forwards and backwards repeatedly, according to the extent of gloss or smoothness required.

Mr. Wyatt on American Super-calendering.—

Mr. Wyatt, on a recent visit to America, had many opportunities of witnessing the systems of manufacture adopted there, and subsequently delivered an interesting address to the members of the Paper-Makers' Club,* in which he acknowledged the superiority of the high-class printing papers for book-work, which has so often been the subject of recognition in this country. Indeed, if we compare the surface of the paper used even for ordinary technical journals in America and that generally adopted for our own periodicals of a similar class, we are constrained to admit that the difference is in favour of our transatlantic competitors. "In the manufacture of high-class super-calendered printing papers," Mr. Wyatt observes, "for fine book-work, or as they call them book papers, the Americans certainly excel. Whether this be

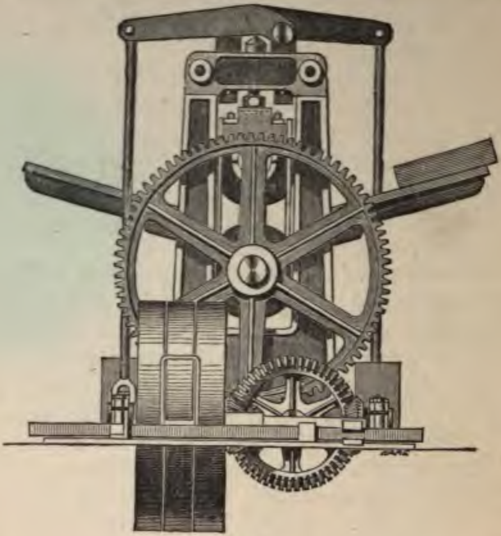

Fig. 40.

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* *Paper-Makers' Monthly Journal*, April 15th, 1889.

due to the kind of raw material used, to the almost universal use of the refining-engine, which renders the pulp very soft and mellow, or to the state of perfection to which they have brought the art of super-calendering, or perhaps due to all three, I could not exactly determine. The material generally used for this class of paper is poplar chemical fibre and waste paper to the extent of 50 per cent., and even up to 75 and 80 per cent. of the total fibre, the balance being rags, or, in cheaper qualities, sulphite wood pulp; the stuff is all mixed together in large beaters, holding from 800 lbs. up to 1,500 lbs. of pulp, where it is about half beaten, and then finished in one or other form of refining-engine.

"The Americans have, I think, more thoroughly studied the question of super-calendering paper than we, and in this respect get better results and better work. The paper is mostly slit and trimmed on the paper-machine, and reeled up in from two to four widths by an ingenious contrivance called the *Manning-winder*, which automatically keeps the tension constant on each of the reels, whatever the diameter, and is super-calendered in narrow widths on small calenders. These calenders are from 36 inches to 42 inches wide, and consist of a stack of 9 to 11 rolls, alternately chilled iron, and cotton or paper; the paper is passed through the rolls two or three times, never less than twice, under great pressure applied by hand-screws. The power required is very high, being from 40 to 50 h.p. for each calender, and the speed from 450 feet up to 600 feet per minute. The paper is not usually damped before calendering, but is left rather under-dried from the machine; neither is steam heat used in the rolls, which get very warm, owing to the high speed at which they run. The rolls are driven entirely by straps, the arrangements for the fast and slow speed and for reeling on and off the paper being well designed and worked out; the main strap, running at high speed, runs on a loose pulley on the shaft of the bottom roll, by means of a powerful friction clutch; this pulley can be made a tight one. On this same bottom shaft is keyed a multiple V-shaped grooved friction pulley. Another, and independent shaft, driven from the main shaft by a crossed belt, has a small grooved pulley keyed on it, which can be thrown in and out of gear with the large grooved pulley. Strap-driving is thus secured throughout, and the speed can be increased gradually without jerks, from the starting up to the fastest speed by working the levers, gearing the friction clutch and pulleys slowly."

In reference to the high finish of American papers, we are disposed to attribute this mainly to the nature of the chief raw material used—wood fibre. In the year 1854, when specimens of Mr. Charles Watt's wood-fibre paper were first printed upon, the remarkable gloss of the wood paper attracted much attention, and it was noticed that the impression of the ink appeared to be well *on the surface of the paper*, and not, as was often the case with ordinary printing papers of the time, partially absorbed by the paper itself. Mr. Wyatt states that poplar chemical fibre and waste paper to the extent of 50 per cent., and even up to 75 and 80 per cent., are used, the balance being rags; now since the waste paper in all probability would be composed largely of wood fibre, and as, in the cheaper qualities, sulphite wood pulp is used in lieu of rags, it will be fair to assume that the chief basis of the highly-finished papers for which the Americans are justly famous is wood fibre, and we believe that there is no other variety of cellulose which is so susceptible of producing a naturally glossy paper as that which is obtained from wood by the soda process.

Mr. Arnot on Finishing.—Mr. Arnot makes the following observations respecting the finishing of paper:—"The paper may be slit into widths, suitable for wet calenders, or may be cut up into sheets, and glazed by the plate or board calenders. The former method of surfacing or finishing has come extensively into use in recent times, the labour involved being much less than in the older method of finishing in sheets. Still, however, the plate calenders are kept at work upon the higher classes of goods, it being possible to give almost any degree of surface to good paper by that means. There is little doubt, too, that the paper glazed by the plate rolls retains its original softness to a greater degree than that passed through web calenders. In the latter it is exposed in one thickness to great pressure, and is thinned in consequence; whereas, when the sheets are made up into piles, along with copper or zinc plates, there is a certain amount of spring or elasticity in the treatment which largely counteracts the crushing action of the rolls. The web calenders consist of a series of rollers erected in a vertical frame, and between these the paper winds, beginning at the top and coming downwards, so that the pressure gradually increases as the paper moves on its journey. It will be observed that the under rolls have to bear the weight of the upper ones, and that consequently the pressure on the paper will be greater the lower down it descends. Many of the rollers themselves are now made of paper, and as these possess a slight degree of elasticity, and take a high polish, they are alternated with iron rollers with good effect. The paper-rolls are made by sliding an immense number of circular sheets, perforated in the centre, on to an iron core or shaft, pressing these close together by hydraulic action, and trimming them off on the lathe. The plate or broad calenders consist only of two rollers, the upper one heavily weighted, preferably by compound levers. Between these rollers the sheets of paper, alternated with plates of copper or zinc, and made up into bundles about an inch in thickness, are passed backwards and forwards, the reciprocating action being produced by the movement of a lever in the hand of an attendant. The metal and paper sheets of different bundles may be interchanged, and the process repeated with the effect of increasing the beauty and equality of the finish."

Cutting.—*Revolving Knife.*—When paper is to be used in a continuous printing-machine, or, as is often the case, has to be exported in the web, it is supplied in rolls; otherwise it is cut into sheets before leaving the mill. The form of cutter generally used is what is termed the *revolving knife-cutter*, an illustration of which, as manufactured by Bertrams, Limited, is shown in Fig. 41. At A is shown a series of webs, the paper from which is drawn forward by the rolls, B, and is then slit into suitable widths, and the margin at the same time pared by circular knives, one of which is shown at C. It then passes through a pair of leading-rolls, after which it comes in contact with a knife, D, attached to a revolving drum, E, pressing against a dead knife not shown in the engraving. The sheets, as they are thus cut, drop upon a travelling felt or apron, F, from which they are lifted and placed in piles, by boys or girls standing on each side of the felt. These machines will cut eight webs at one time.

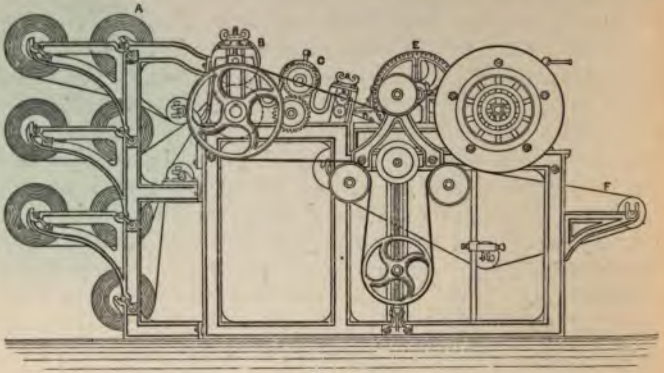

Fig. 41.

Bertrams' Single-sheet Cutter.—In cases where it is necessary that the sheets should be cut with great uniformity, as in the case of paper bearing a water-mark, in which it is requisite that the design should appear exactly in the centre of the sheet, the ordinary cutter is not found to be sufficiently reliable; a machine termed a "single-sheet cutter" is therefore used for this purpose, of which an illustration is shown in Fig. 42. The paper is led direct from the paper-machine, or from a reel frame, to the drawing-in rolls, A; after which it passes through the circular slitting-knives, B; from here it is led by the roller C to a large wood-covered drum, D, and at the front of this drum the sheets are cut by the cross-cutting knives, E. There are two cast-iron tapered cones, with belt guide for adjusting the speed; a fly-wheel to promote steadiness in working; a series of wrought-iron levers, cranks, eccentrics, shafts, etc., for accurately regulating the travel of paper and the cut of the horizontal knives; a small pasting table is also fitted across the machine for mending broken sheets.

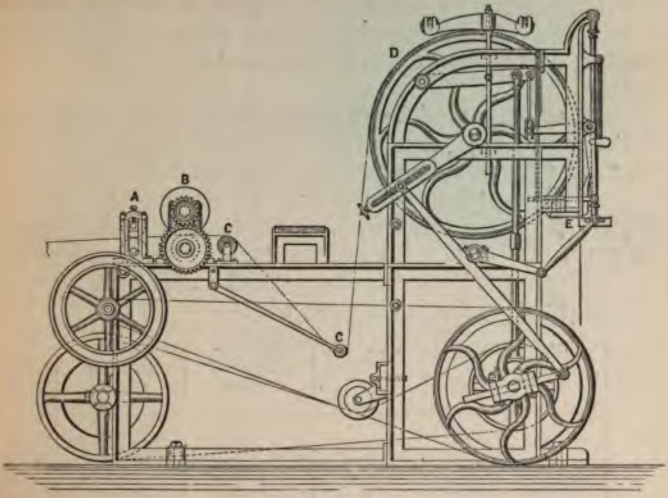

Fig. 42.

Packing the Finished Paper.—The paper, after it leaves the cutting-machine, is conveyed to the *finishing-house*, where it is carefully examined by women, who cast aside all defective or damaged sheets, which, under the trade names of "imperfections" or "retree," are sometimes disposed of, at a lower rate, to the customer for whom the order is executed. In the warehouse these imperfections are marked with a capital R on the wrapper, or two crosses, thus **X X**. If the paper is broken, it is sometimes marked B **X X**; it is not generally the custom, however, to sell imperfections, but to return them to the beater-man, to be re-converted into pulp. The perfect sheets are then counted, and packed up in reams consisting of 480 to 516 sheets.

Sizes of Paper.—The various sizes of paper are known in the stationery trade under different designations, as demy, crown, double crown, royal, imperial, etc. As paper is generally purchased according to weight, the various weights per ream are also distinguished with the size of the paper, as 16 lb. demy, 22 lb. double crown, and so on. The following table shows the sizes of some of the writing and printing papers in common use:—

Name.	Writing Papers.	Printing Papers.
	Inches.	Inches.
Foolscap	17 × 13¼	17 × 13¼
Small post (or post) . . .	18¾ × 15¼	18¾ × 15¼
Crown		20 × 15
Double crown		30 × 20
Demy		22½ × 17¾
Royal		25 × 20
Imperial		30 × 22
Double demy		35½ × 22½
Double royal		40 × 25

CHAPTER XV.

COLOURED PAPERS.

Coloured Papers.—Colouring Matters used in Paper-Making.—American Combinations for Colouring.—Mixing Colouring Materials with Pulp.—Colouring Paper for Artificial Flowers.—Stains for Glazed Papers.—Stains for Morocco Papers.—Stains for Satin Papers.

Coloured Papers.—There are several methods by which any desired shade of colour may be imparted to paper, which are as follows:—

1. By blending with the pulp in the beating-engine some insoluble substance, such as smalts blue—a kind of glass coloured by oxide of cobalt—ultramarine, yellow ochre, etc.

2. By adding a coloured liquid, which simply dyes or stains the fibre.

3. By using rags which are already coloured, in proportions to give the required shade, in which case of course the process of bleaching must be omitted.

4. By employing two substances, as yellow prussiate of potash (ferrocyanide of potassium) and a persalt of iron, for example, which, when combined, yield the requisite blue tint—Prussian blue.

By this latter method the buff shade given to what is termed *toned paper* is effected, by using a solution of copperas (sulphate of iron) and an alkaline solution, or by using a solution of pernitrate of iron. In experimenting in this direction we have found that a mixture of solutions of sulphate of iron and bichromate of potassa produce an agreeable and permanent buff tint. The solutions may be added to the pulp alternately, or may be first mixed and then at once put into the beater. From 2 to 3 ozs. of each salt for each gallon of water may be used if the solutions are to be mixed before using; but when applied separately the solutions may be used in a more concentrated condition.

Colouring Matters used in Paper-Making.—The following substances, used either alone or mixed in suitable proportions, are employed in colouring pulp for paper-making:—

- Smalts blue.
- Prussian blue.
- Indigo blue.
- Aniline blues.
- Aniline reds, including eosine.
- Cochineal, for pink, etc.
- Brazil wood, which imparts either a fine red or orange-brown colour, according to the treatment it has undergone.
- Logwood, for violet colours.
- Chrome yellow and orange chrome.
- Orange mineral
- Copperas, for mixing with other substances.
- Venetian red.
- Yellow ochre.
- Quercitron, or oak-bark.
- Nutgalls
- Lamp black.

Blue.—The coarser kind of paper used for packing is prepared from rags blued with indigo, which, when reduced to pulp, are not subjected to the process of bleaching. The finer kinds of paper are blued in various ways, but the chief material used is what is known as artificial ultramarine, of which there are many qualities in the market, to which reference is made in another chapter. Prussian blue is also used, but this is usually produced directly in the beating-engine by adding in solution, 95 parts of sulphate of iron and 100 parts of ferrocyanide of potassium (yellow prussiate of potash). Smalts blue, which was formerly much used before the introduction of artificial ultramarine, is still preferred for high-classed papers as the colour is more permanent. To obtain smalts in an exceedingly fine state of division the best plan is to grind the colour in a little water, and then to separate the finest particle by the process of *elutriation*, that is, by diffusing the reduced mass through a large volume of water, and after allowing the larger particles to subside, pouring off the liquor in which the finer particles are suspended, to a separate vessel, in which they are allowed to subside. If this operation is carefully conducted the smalts may be obtained in an exceedingly fine state of division, and we have found that in this state the colour blends well with the pulp, and has little or no disposition to sink through it, but produces a uniform colouring throughout.

American Combinations for Colouring.—Hofmann gives the following examples of the combination of colours which have been adopted by American manufacturers:—

Yellow Gold Envelope of fine quality is made of—

Bichromate of potash	10 lbs.
Nitrate of lead	18 ,,
Orange mineral	56 ,,
Porous alum	30 ,,

each substance being separately dissolved and added to 400 lbs. of pulp.

Orange-red Gold Envelope :—

Bichromate of potash	7 lbs.
Nitrate of lead	10½ ,,
Orange mineral	60 ,,
Porous alum	20 ,,

These substances are dissolved separately and added to 400 lbs. of pulp.

Buff Envelope of fine deep shade is made from—

Bichromate of potash	3 lbs.
Nitrate of lead	5 ,,
Orange mineral	10 ,,
American ochre	20 ,,
Porous alum	30 ,,

Some half-stuff of red jute bagging. For 400 lbs. of pulp.

Tea-Colour is made from a decoction of quercitron bark, the liquid being poured into the engine, and 2 lbs. of copperas in solution are added for every gallon of the bark extract. A little ultramarine may be used to brighten the colour.

Drab.—Venetian red, well washed, added to a pulp of tea-colour made as above will give a fine drab.

Brown is composed of several colours, or a very fine dark green tea-colour brown, containing tea, buff, drab, and ink-grey, may be made of—

Quercitron bark liquid	15	gals.
Bicarbonate of soda	2	lbs.
Venetian red	4	,,
Extract of nutgalls	2½	,,
Copperas	18	,,
Porous alum	30	,,

The above proportions are for 400 lbs. of pulp.

The large proportion of alum prescribed in all the above examples serves as a mordant, and also, with the addition of resin soap, for sizing. All the above mixtures should be passed through a No. 60 wire-cloth into the beating-engine.

Mixing Colouring Materials with Pulp.—It will be readily understood that when paper is sized in the pulp, as Mr. Hofmann points out, the resinous alumina surrounds the fibres and prevents the colouring materials from penetrating them. In such cases the colouring materials are only loosely held, and a portion must therefore be lost in the machine. If added to the pulp before it is sized they become thoroughly mixed with the fibres, and with them enveloped by the size. The pulp should always be coloured before it is sized, except in cases where the alum or resin soap would injure the colours, or be injured by them. While the pulp is being sized and coloured, the finishing touch is given by the engine-man, who examines it and empties it into the stuff-chest.

Colouring Paper for Artificial Flowers.—Davis gives the following recipes for colouring one ream of paper of medium weight and size, sap colours only being used, and principally those containing much colouring matter. The gum arabic given in the recipes is dissolved in the sap-liquor.

Blue (dark) 1.—Mix 1 gallon of tincture of Berlin blue with 2 ozs. each of wax soap and gum tragacanth. 2. Mix ¾ gallon of tincture of Berlin blue with 2 ozs. of wax soap, and 4¼ ozs. of gum tragacanth.

Crimson.—Mix 1 gallon of liquor of Brazil wood compounded with borax, 2 ozs. wax soap and 8¾ ozs. of gum arabic.

Green.—1. Take ½ gallon of liquor of sap-green*, 4¼ ozs. of indigo rubbed up fine, 1 oz. of wax soap, and 4½ ozs. of gum arabic. 2. ½ gallon of sap-green liquor, 4¼ ozs. of distilled verdigris, 1 oz. of wax soap, and 4½ ozs. of gum arabic.

Yellow (golden).—Mix 6½ ozs. of gamboge with 2 ozs. of wax soap.

Yellow (lemon).—1. Compound 1 gallon of juice of Persian berries with 2 ozs. of wax soap and 8¾ ozs. of gum arabic. 2. Add to 1 gallon of quercitron liquor, compounded with solution of tin, 2 ozs. of wax soap, and 8¾ ozs. of gum arabic.

Yellow (pale).—Mix 1 gallon of fustic, 2 ozs. of wax soap, and 8¾ ozs. gum arabic.

Yellow (green).—Compound 1 gallon of sap-green liquor with 2 ozs. each of distilled verdigris and wax soap, and 8¾ ozs. of gum arabic.

Red (dark).—1 gallon of Brazil-wood liquor, 2 ozs. of wax soap, and 8¾ ozs. of gum arabic.

Rose Colour.—Mix 1 gallon of cochineal liquor with 2 ozs. of wax soap, and 8¾ ozs. of gum arabic.

Scarlet.—1. Mix 1 gallon of Brazil wood liquor compounded with alum and a solution of copper, with 2 ozs. of wax soap, and 8¾ ozs. of gum arabic. 2. Mix 1 gallon of cochineal liquor compounded with citrate of tin, with 2 ozs. of wax soap, and 8¾ ozs. of gum arabic.

Stains for Glazed Papers.—Owing to the cheapness of these papers glue is used in lieu of the more expensive gums; 1 lb. of glue dissolved in 1¼ gallon of water; the proportions of colouring materials are given for 1 ream of paper of medium weight and size.

Black.—1. Dissolve 1 lb. of glue in 1¼ gallon of water; triturate this with lampblack (1 lb.) previously rubbed up in rye whiskey; Frankfort black, 2¾ lbs.; Paris blue, 2 ozs.;

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* The berries of *Rhamnus catharticus* made into a decoction by boiling.

wax soap, 1 oz.; then add liquor of logwood, 1½ lb. 2. 1½ gallon of liquor of logwood compounded with sulphate of iron, 1 oz. of wax soap, and 4½ ozs. of gum arabic.

Blue (azure).—1¼ gallon of glue liquor, as before, mixed with 1½ lb. Berlin blue, 2¾ lbs. powdered chalk, 2¼ ozs. of light mineral blue, and 2 ozs. of wax soap.

Blue (dark).—Mix with 1¼ gallon of glue liquor, 4½ lbs. of powdered chalk, 4¼ ozs. of Paris blue, and 2 ozs. of wax soap.

Blue (pale).—1. Mix ½ gallon of tincture of Berlin blue and 1 oz. of wax soap with 3½ ozs. of solution of gum tragacanth. 2. Take 1¼ gallon of glue liquor and mix with 4 lbs. of powdered chalk and 2 ozs. each of Paris blue and wax soap.

Brown (dark).—1. 1¼ gallon of glue liquor, mixed with 6 lbs. each of colcothar (jewellers' rouge) and English pink, 1½ lb. of powdered chalk, and 2 ozs. of wax soap. 2. Dissolve 1 oz. of wax soap and 4½ ozs. of gum arabic in ½ gallon of good Brazil-wood liquor, and add a like quantity of tincture of gallnuts.

Green (copper).—Mix in 1¼ gallon of glue liquor 4 lbs. of English verdigris, 1½ lb. of powdered chalk, and 4 ozs. of wax soap.

Green (pale).—Mix with 1¼ gallon of glue liquor 1 lb. of Bremen blue, 8½ ozs. of whiting, 1 oz. of pale chrome yellow, and 2 ozs. of wax soap.

Lemon Colour.—Mix in 1¼ gallon of glue liquor 13 ozs. of lemon chrome, 2 lbs. of powdered chalk, and 2 ozs. of wax soap.

Orange-Yellow.—Mix in 1¼ gallon of glue liquor 2 lbs. of lemon chrome, 1 lb. of Turkish minium, 2 lbs. of white lead, and 2 ozs. of wax soap.

Red (cherry).—Mix in 1¼ gallon of glue liquor 8½ lbs. of Turkey red, previously mixed up with ¼ gallon of Brazil-wood liquor, and 2 ozs. of wax soap.

Red (dark).—Mix ¾ gallon of Brazil-wood liquor with wax soap 1 oz., and gum arabic 4½ ozs.

Red (pale).—To 1¼ gallon of glue liquor is to be added 8¼ lbs. of Turkey red previously rubbed up with 2 ozs. of wax soap.

Violet.—4½ ozs. of gum arabic, and 1 oz. of wax soap are to be mixed with ½ gallon of good logwood liquor. When the gum is dissolved, mix with it enough potash to form a mordant.

Stains for Morocco Papers.—For 1 ream of paper of medium size and weight the following recipes are recommended :—

Black.—8¾ ozs. of good parchment shavings are dissolved in 1½ gallon of water; into this liquid is to be stirred lampblack, 1 lb., Frankfort black, 3 lbs., and Paris blue, 1¾ oz.

Blue (dark).—Dissolve parchment shavings, as before, and mix in 8¼ lbs. of white lead and 4½ lbs. of Paris blue.

Blue (light).—Dissolve parchment shavings, as before, and mix in 8¾ lbs. of white lead and 2¼ ozs. of Paris blue.

Green (dark).—Dissolve 13 ozs. of parchment shavings in 2½ gallons of water, and mix in 10 lbs. of Schweinfurth green.

Green (pale).—Prepare solution of parchment as in the last, and mix with 8¾ lbs. of Schweinfurth green and 1 lb. of fine Paris blue.

Orange-Yellow.—8¾ ozs. of parchment shavings are to be dissolved in 1½ gallon of water, and then mixed with 1½ lb. of lemon chrome, 8¾ ozs. of orange chrome, and 1 lb. of white lead.

Red (dark).—To the same quantity of parchment liquor as the last is to be added 7¾ lbs. of fine cinnabar, and 1 lb. of Turkey red.

Red (pale).—To the same quantity of parchment liquor add 8¾ ozs. of Turkey red.

Violet (light).—To 1½ gallon of parchment liquor add 4¼ lbs. of white lead, 13 ozs. of light mineral blue, and 8¾ ozs. of scarlet lake.

Violet (dark).—To 1½ gallon of parchment liquor add 3¾ lbs. of white lead, 1 lb. of pale mineral blue, and 8¾ ozs. of scarlet lake.

Yellow (pale).—To 1½ gallon of parchment liquor add 2 lbs. of light chrome yellow and 8¾ ozs. of white lead.

Stains for Satin Papers.—For each ream of paper of medium weight and size the following recipes are given :—

Blue (azure).—13 ozs. of parchment are dissolved in 2½ gallons of water and mixed with 3 lbs. of Bremen blue, 1¾ lb. of English mineral blue, and 4½ ozs. of wax soap.

Blue (light).—8¾ ozs. of parchment are to be dissolved in 1½ gallon of water. and to be mixed with light chrome yellow, 13 ozs. ; colcothar, 6½ ozs. ; Frankfort black, 2 ozs. ; powdered chalk 3 lbs., and wax soap, 3½ ozs.

Brown (reddish).—1½ gallon of parchment liquor as the last, to which is added yellow ochre, 1 lb. ; light chrome yellow, 4½ ozs. ; white lead, 1 lb. ; red ochre, 1 oz., and wax soap, 3½ ozs.

Brown (light).—1½ gallon of parchment liquor, as before, to which is added 13 ozs. of light chrome yellow, 6½ ozs. of colcothar, 2 ozs. of Frankfort black, 3 lbs. of powdered chalk, and 3½ ozs. of wax soap.

Grey (light).—1½ gallon of parchment liquor is mixed with 4¼ lbs. of powdered chalk, 8¾ ozs. of Frankfort black, 1 oz. of Paris blue, and 3½ ozs. of wax soap.

Grey (bluish).—To the above quantity of parchment liquor add 4¼ lbs. of powdered chalk, 1 lb. of light mineral blue, 4¼ ozs. of English green, 1¾ oz. of Frankfort black, and 3½ ozs. of wax soap.

Green (brownish).—To the same quantity of parchment liquor add Schweinfurth green, 1 lb. ; mineral green, 8¾ ozs. ; burnt umber and English pink, of each 4¼ ozs. ; whiting, 1 lb., and wax soap, 3½ ozs.

Green (light).—To the same quantity of parchment liquor add English green and powdered chalk, of each 2¾ lbs., and 3½ ozs. of wax soap.

Lemon Colour.—To the same quantity of parchment liquor add lemon chrome, 1½ lb.; white lead 1 lb., and wax soap, 3½ ozs.

Orange-Yellow.—Parchment liquor as before, 1½ gallon, to which is added lemon chrome, 4¼ lbs.; Turkey red, 8¾ ozs.; white lead, 1 lb., and wax soap, 3½ ozs.

Rose Colour.—1½ gallon of parchment liquor as before, to which is added ¾ gallon of rose colour prepared from Brazil wood and chalk, and 6½ lbs. of wax soap.

Violet (light).—1½ gallon of parchment liquor as above, mixed with light mineral blue and scarlet lake, of each 1½ lb.; white lead, 1 lb., and wax soap, 3½ ozs.

White.—To 1½ gallons of parchment liquor is added fine Kremnitz white, 8¾ lbs., Bremen blue, 4¼ ozs., and wax soap, 3½ ozs.

Silver White.—1½ gallon of parchment liquor mixed with Kremnitz white, 8¾ lbs., Frankfort black, 8¾ ozs., and wax soap, 3½ ozs.

Pale Yellow.—1½ gallon of parchment liquor, to which is added 4½ lbs. of light chrome yellow, 1 lb. of powdered chalk, and 3½ ozs. of wax soap.

CHAPTER XVI.

MISCELLANEOUS PAPERS.

Waterproof Paper.—Scoffern and Tidcombe's process.—Dr. Wright's process for preparing Cupro-Ammonium. — Jouglet's process. — Waterproof Composition for Paper.—Toughening Paper.—Morfit's process.—Transparent Paper.—Tracing Paper.—Varnished Paper.—Oiled Paper.—Lithographic Paper.—Cork Paper.—New Japanese Paper.—Blotting Paper.—Parchment Paper —Test Papers.

Waterproof Paper.—*Scoffern and Tidcombe's Process.*—In this process, for which a patent was granted in 1875, the well-known solubility of cellulose in cupro-ammonium is taken advantage of, for the purpose of producing waterproof paper by destroying its absorptive properties. After the paper is made and dried in the usual way by the paper-making machine, it is led through a bath of cupro-ammonium, having a roll or rollers therein, or in connection therewith, either on reels on which the paper is reeled, or from the continuous web of paper itself directly from the machine, and from this bath it is led over a table of wire-cloth, or india-rubber, or over a series of rollers forming a table, under which steam-pipes are placed for the purpose of "setting," or partially drying, the web ; it is then led over suitable reels in a hot-air chamber to season or finish the treated paper, which is then cut as the paper runs, by the ordinary cutting machine, into the required sheets. The chamber in which the paper is treated is ventilated as follows :—Over the bath and hot-air chamber is another chamber having openings leading into the hot-air chamber, and at these openings a steam-blast, or fan-blast, is applied, which ventilates the chamber in which the paper is heated, and drives the ammonia into contact with either sulphurous or hydrochloric acid, and by this means the ammonia is recovered in a solid form which would otherwise be wasted.

The inventors also incorporate hydrated oxide of copper with paper pulp, so that after it is made into paper it has only to be subjected to the action of ammonia, as ordinarily done, or to the action of gaseous ammonia mingled with steam. Brown papers are strengthened and glazed by passing them through a bath of pulp containing cupro-ammonium, either with or without pitch, tar, or other resinous matters. It is well known that by passing paper through a cupro-ammonium bath it is surface dissolved and glazed by its own material, and if it be desired to unite two or more sheets together this is the most economical way of conducting the operation ; but if it be desired to strengthen and glaze a single thickness of paper or millboard, it is considered undesirable to make the glaze by dissolving a portion of the paper itself. In this case the inventors pass the web or sheet of paper through a bath, not of cupro-ammonium simply, but of cupro-ammonium in which ligneous material is already dissolved ; and when the glazing of brown paper is to be effected, they prefer to fortify the bath with tar, pitch, marine glue, or other resinous materials. By this process, panels and tiles may be manufactured from millboard, or thick sheets of ligneous material made from pulp already incorporated with hydrated oxide of copper. The panels, etc., are passed, by means of an endless web, through a bath of ammoniacal solution, or the vapour of ammonia and steam, and the tiles or panels may be surface-glazed by exposing them while moist to the action of fluo-silicic acid gas, by which silica is deposited in the material and on its surface.

Dr. Wright's Process for preparing Cupro-ammonium.—This process, which has been adopted at the Willesden Paper Mills, may be thus briefly described :—In the first part of the process, metallic copper, in small lumps, solid metal, or clippings, etc., is covered with a solution of ammonia in water, or with a weak solution of cupro-ammonium hydrate, containing an amount of free ammonia in solution dependent upon the strength of the copper solution ultimately required; a current of air is then caused to pass through the whole by means of an air-pump, in such a manner that the bubbles of air pass over and amongst the fragments of metallic copper, which, if in small particles, may be advantageously kept in suspension by any convenient agitator. In a few hours the liquid becomes saturated with as much copper as it can dissolve, the rate of solution varying with the form of the vessel containing the materials, the strength of the ammoniacal fluid, and the rate of the passage of the stream of air. To carry this process into effect, metallic copper in fragments of convenient size is loosely piled inside a vertical tube or tower, and water is allowed to trickle from a pipe over the copper so as to keep its surface moist. At the base of the tower a current of air, mixed with ammonia gas, is caused to pass into the tower, so as to ascend upwards, meeting the descending water as it trickles over the copper. Under these conditions the copper becomes oxidised, and the water dissolves firstly the ammonia gas, and, secondly, the oxide of copper formed, so that the liquor which passes out at the base of the tower is a solution of cupro-ammonium hydrate, the strength of which depends on the proportions subsisting between the bulk of the mass of copper, the quantity of water trickling over it, and the amount of air and ammonia gas supplied in a given time. As an example of the method of carrying out the above process, the inventor proceeds as follows:—He constructs a vertical iron tower which may be ten inches in internal diameter and ten feet in height, and this is filled with scraps of sheet copper. On this water is allowed to trickle, whilst at the base of the tower a mixture of air and gaseous ammonia is allowed to pass upwards through the tower, by which a solution of cupro-ammonium is formed, which is allowed to trickle out at the base of the tower into a tank. It has been found advantageous to use a series of towers, allowing the air and ammonia gas that pass out at the top of the first tower to enter at the bottom of the second tower, and so on successively throughout the series. The weaker solutions produced in the later towers of the series are used instead of water in the earlier towers, so that practically all the ammonia gas originally used is obtained in the form of cupro-ammonium hydrate solution, issuing from the first tower of the series.

The cupro-ammonium process, as carried on at the Willesden Mills, is applied to ropes, netting, etc., by immersing them in a solution of cupro-ammonium, which, when they are subsequently dried, gives them a varnished appearance, while at the same time, the fibres having become cemented together by the action of the cupro-ammonium, their strength is increased. By the same process paper, canvas, and other manufactured articles are rendered waterproof. A concentrated solution of cupro-ammonium may also be used for securing envelopes, whereby the adhesion of the surfaces of the paper is rendered perfect, and the only means of opening the envelope is by cutting or tearing the paper.

Jouglet's Process.—This process, which with modifications has been adopted by others, is based on the solvent action on cellulose of a solution of oxide of copper in ammonia. A quantity of this solution is placed in a tank, and the paper rapidly passed over and in contact with the surface of the liquid, by means of suitable rollers in motion. The paper is afterwards pressed between a pair of rolls and dried by the ordinary drying cylinders. The brief contact of the paper with the liquid occasions just sufficient action on the cellulose to have the effect of an impermeable varnish.

Waterproof Composition for Paper.—The following composition for rendering paper waterproof for roofing and flooring purposes has been patented in America.* By preference good, hard manilla paper is selected, and a composition of the following ingredients is applied with a brush, or by means of rollers:—Glue, 2 lbs., is dissolved in 3 gallons of crude petroleum, of about the density of 33° B. at 60° F.; 35 gallons of resin oil, and about half a pint of oil of eucalyptus, which will have the effect of destroying the objectionable odour of the resin oil. To this mixture is further added about 4 gallons of any ordinary drier. The above ingredients are to be thoroughly mixed by agitation, and the composition brushed over the paper in a room heated to about 80° F., and allowed to dry. It is said that paper thus coated will exclude wind, cold, dampness, and dust.

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* *Paper Trade Journal,* New York, April 20th, 1889.

Toughening Paper.—*Morfit's Process.*—The object of the following process is to produce a paper "toughened in a degree and quality distinctively from any other in the market," and is applicable to all kinds of paper, but more particularly to those made with inferior grades of pulp for printing newspapers, and for wrapping papers. The means employed are the seaweeds which form glutinous liquors with water, such as Carrageen, or Irish moss, Agar-agar, and the like. Any of such seaweeds may be employed, either separately or mixed with another of its kind, according to the judgment of the operator and the sort of paper to be manufactured, but some seaweeds are superior to others for this purpose. The raw seaweed is first washed, and then boiled with water until all the soluble matter has been extracted, and the resulting liquor is then strained. The hot strained liquor forms the bath in which sheets of paper or pulp are to be treated. If desired, resin soap and aluminous cake may be added to the glutinous liquor, but these "serve rather to size and make the paper rustle than increase its toughness." If the paper is to be treated in the form of sheets or web, it is to be passed, as it leaves the wire-cloth in which it is formed, through a hot solution of the seaweed alone, or mixed with resinous soap and aluminous cake, and dried by means of suitable machinery. To apply it to the pulp, the latter is to be diffused in the hot liquor, and the sheets or web made therefrom in the usual manner. The proper proportions of seaweed, untearable, and is sufficiently transparent to admit of its being used as a substitute for window glass; it takes all colours well, and in many respects resembles old window glass.—*Board of Trade Journal.*

Blotting Paper.—This paper, requiring to be very absorbent, is not sized, but is prepared with starch alone, which, while holding the fibres together, does not affect the absorbent property of the paper. Dunbar gives a recipe for making blotting paper which has been found successful, and from which we make a few extracts. In selecting materials for blotting, of high-class, cotton rags of the weakest and tenderest description procurable should be chosen. Boil them with 4 lbs. of caustic soda to the cwt.—that is, if you have no facilities for boiling them in lime alone. When furnished to the breaking-engine, wash the rags thoroughly before letting down the roll; when this is done, reduce them to half-stuff, and as soon as possible convey them to the potcher. When up to the desired colour, drain immediately. The breaker-plate should be sharp for blottings, and the beater-roll and plate also in good order, and the stuff beaten smartly for not more than an hour and a half in the engine. For pink blottings furnish two-thirds white cottons and one-third of Turkey reds if they can be got, or dye with cochineal to desired shade; empty down to the machine before starting, and see that the vacuum pumps are in good condition. Remove weights from couch-roll, and if there are lifting screws raise the top couch-roll a little. Take shake-belt off, as the shake will not be required. Press light with first press, and have the top roll of the second press covered with an ordinary jacket similar to couch-roll jacket. Dry hard, and pass through one calender with weights off, and roll as light as possible, just enough to smooth slightly.

Parchment Paper.—This paper, which is extensively used for covering jars and pots for pickles and jams, is prepared, according to the process of Poumarède and Figuier, as follows:—White unsized paper is dipped for half a minute in strong sulphuric acid, specific gravity

1·842, and afterwards in water containing a little ammonia. By Gaine's process (1857) unsized paper is plunged for a few seconds into sulphuric acid diluted with half to a quarter of its bulk of water (the acid being added to the water), and the solution allowed to cool until of the same temperature as the air. The paper is afterwards washed with weak ammonia. This process, which has been extensively worked by Messrs. De la Rue and Co., produces a far better material than the foregoing.

Mill and Card-board.—In the manufacture of boards refuse materials of all kinds that occur in the paper-mill may be used, and these are sorted according to the quality of boards for which they are best suited. After being well beaten the resulting mass is mixed with suitable proportions of rag pulp, kaolin, chalk, white clays, &c. There are four principal processes by which boards are manufactured, namely,

1. By superposing several sheets of paper and causing them to unite by a sizing material.
2. By superposing several wet leaves at the time of couching.
3. By moulds provided with thick deckles.
4. By special machines similar to those used for making continuous webs of paper, but without a drying cylinder, the sheets being dried in the open air or in a heated room.

The third method is only adopted for boards of moderate thickness, as an excess of pulp would render the draining difficult.

Making Paper or Cardboard with two Faces by Ordinary Machine.—By this process, recently patented by Mr. A. Diana, all kinds of thin or thick paper or cardboard are manufactured with two different faces by means of the ordinary paper-machine, having a single flat table with a single wire-gauze web, without requiring a second metallic web. For this purpose the two pulps are prepared separately, and one is caused to pass on to the web in an almost liquid condition; this is allowed to drain off sufficiently, and the second pulp (also in a liquid condition) is then passed uniformly upon the whole surface of the previous layer. The water drains off from this layer through the first layer, and the paper or cardboard is thus directly formed with two different faces, the subsequent operations being as ordinarily employed in paper-making. The space between two of the suction cases employed for drawing off the water in the pulp is a suitable point for the distribution of the diluted second pulp, which is almost liquid.

Test Papers.—These papers, which are extensively used both in the laboratory and the factory, for determining the presence of acids or alkalies in various liquids, may be prepared as follows:—*Litmus paper*, for detecting the presence of acids, is prepared by first making an infusion of litmus. Reduce to a paste with a pestle and mortar 1 oz. of litmus, adding a little boiling water; then add more boiling water—from 3 to 4 ozs. in all—and put the mixture into a flask and boil for a few minutes; finally, add more boiling water to make up half a pint, and when cold filter the liquor. To prepare the test paper, a sufficient quantity of the liquid being poured into a flat dish, pieces of unsized paper are steeped in the blue liquid, so that all surfaces may be thoroughly wetted; the paper is then to be hung up by one corner to drain, and afterwards dried. As many sheets of paper as may be required should be treated in this way, and the sheets afterwards cut up into convenient strips for use. *Red litmus paper*, for detecting slight traces of alkali in liquids, may be prepared by dipping a glass rod, previously dipped into a very dilute solution of sulphuric acid, into one-half of the above infusion, repeating the operation cautiously until the liquid turns from blue to a slightly red tint. Unsized paper when dipped in this will acquire a reddish colour which is very sensitive to the action of weak alkaline liquors, and the vapour of ammonia restores the blue colour instantly. *Turmeric paper* is prepared by dipping unsized paper in a decoction of turmeric—about 2 ozs. to the pint. Paper steeped in this solution and dried acquires a yellow colour, which turns brown in alkaline solutions.

CHAPTER XVII.

MACHINERY USED IN PAPER-MAKING.

Bentley and Jackson's Drum Washer.—Drying Cylinder.—Self-Acting Dry Felt Regulator.—Paper Cutting Machine.—Single Web Winding Machine.—Cooling and Damping Rolls.—Reversing or Plate Glazing Calender.—Plate Planing Machine.—Roll Bar Planing Machine.—Washing Cylinder for Rag Engine.—Bleach Pump.—Three-roll Smoothing Presses.—Back-water Pump.—Web Glazing Calender.—Reeling Machine.—Web Ripping Machine.—Roeckner's Clarifier.—Marshall's Perfecting Engine.

APART from the mechanical contrivances which are referred to in various parts of this work, in which their application is explained, it will be necessary to direct attention to certain machines and appliances which are adopted at some of the more advanced paper-mills in this country and in America; but since the various makers of paper-makers' machinery are constantly introducing improvements to meet the requirements of the manufacturer, we must refer the reader to these firms for fuller information than can be given in the limited scope of this treatise. Many of the improvements in paper-making machinery consist in modifications—sometimes of a very important nature—in the construction of certain parts of a machine, whereby the efficiency of the machine as a whole is in some cases considerably augmented. Without offering any critical remarks upon the merits of the respective improvements which have been introduced, it will be sufficient to direct attention to the manufacturer's own description of the principal features of the special mechanical contrivance which he produces for the use of the paper-maker. It may also be said that innumerable patents have been obtained for various improvements in machinery, or parts of machines, engines, etc., which can readily be referred to at the Library of the Patent Office, or any of the public libraries throughout the Kingdom.

Bentley and Jackson's Drum-Washer.—This drum-washer, for use in the rag-engine, is shown in Fig. 43. It has cast-iron ends, strong copper buckets, shaft, stands, lifting-gear, and driving-wheel, but instead of the drum being covered with the ordinary strong brass backing-wire, it is covered with their improved "honey-comb" *backing-plates*, over which the fine wire is wrapped as usual. The honey-comb backing consists of tough rolled brass or copper plates, curved to suit the diameter of the drum, and secured to its ends by cross-bars. It is practicably indestructible, strengthens the drum, and by maintaining its cylindrical form, adds considerably to the durability of the fine covering-wire.

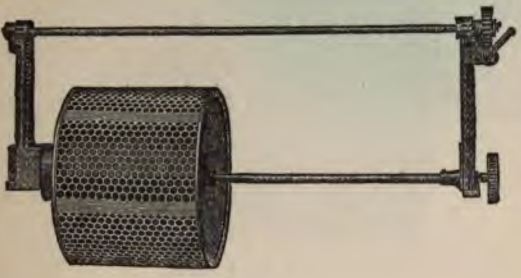


Fig. 43.

Drying Cylinders.—These cylinders, by the same firm, for which patents were obtained in 1872 and 1887, are made with concave and convex ends, the latter type being shown in Fig. 44. The cylinder body is made of hard cast-iron, turned and polished on outside surface. The ends and trunnions are of tough cast iron, turned to fit into their places, and there secured by bolts and nuts by a patented method, whereby no bolts (excepting for the manhole) are put through the metal, an unbroken surface is preserved, and the annoyance of leakage through the bolt-holes is avoided. A manhole and cover is fitted to all cylinders 3 feet in diameter and upwards, and a

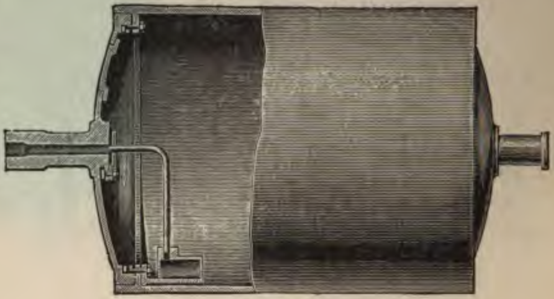
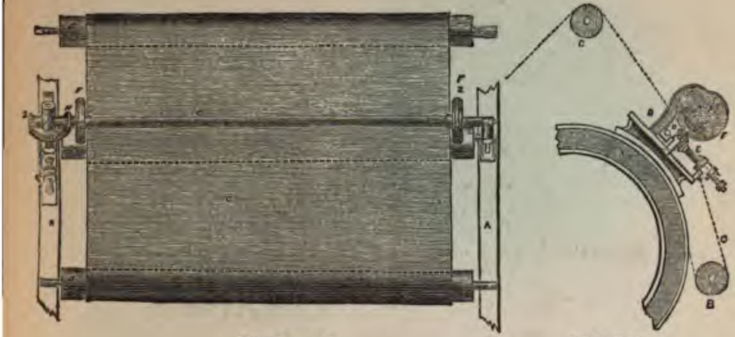


Fig. 44.

water-lifter and pipe to remove the condensed steam. The trunnions are bored to receive nozzles or junctions for admitting steam, and the whole, when completed, is carefully balanced and tested by steam pressure to 35 lbs. per square inch. The firm state that they have made cylinders from 2 to 10 feet in diameter by this system.

Self-acting Dry Felt Regulator.—This contrivance, which is manufactured by Messrs. Bentley and Jackson, is represented in front and side elevation in Fig. 45. A is the framing of the paper-machine, B the felt-rollers, C the dry felt; D is a slide carrying one end of the felt guide-roller B; C is a shaft across the machine, with a pulley F, two-keyed on one end, and a bevel pinion two-keyed on the other end. The pulley F and pinion H are keyed together, and run loose upon the shaft G; I is a bevel-wheel, gearing into the pinions H and 2. The wheel I is connected by a spindle and a pair of bevel-wheels to a screw E, which works through a threaded bush. When the machine is at work, if the felt C should run on one side, it will pass between the pulley F and the guide-roller B, causing the pulley to revolve, and turning the screw E in the threaded bush, thereby moving the slide fixing D and the guide-roller B, which causes the felt to run back. Should the felt run to the other side, it will run in contact with the pulley F 2, and thus reverse the motion of the guide-roller B.



FRONT ELEVATION. SIDE ELEVATION.

Fig. 45.

Paper-cutting Machine.—This machine (Fig. 46), which is manufactured by the same firm, is constructed to cut from one to eight webs simultaneously, in sheets of any required length, from 8 to 60 inches. It is built on the "Verny" principle, and its operation is as follows:—The webs of paper from the reel-rolls are carried by an endless felt, and the paper is drawn off the rolls by travelling cast-iron gripper beams, which firmly grasp the felt and the webs of paper to be cut, the travel of the beams being equal to the length of the sheet of paper to be cut. When the required length of the sheet is drawn from the rolls, a cast-iron clamp, placed close to the dead cross-cut knife, descends and firmly holds the paper until the movable cross-cut knife has cut off the sheets, which fall on a second endless felt, and are placed by the catchers in the usual manner. As soon as the sheets are cut, the clamp is released, and the travelling-grippers are again ready to seize the paper and repeat the operation.

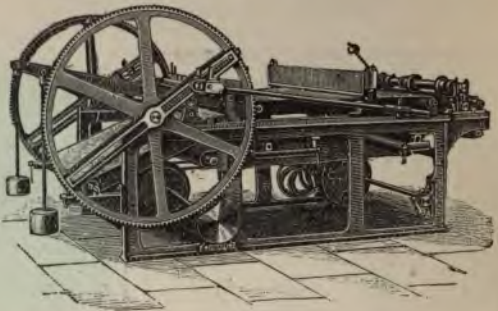


Fig. 46.

Single Web Winding Machine.—This machine (Fig. 47) is constructed for preparing webs of paper for continuous printing-presses. The roll of paper to be prepared is carried by brass bearings having vertical and horizontal screw adjustments attached to standards mounted on a slide, and movable by a screw transversely on the machine to accommodate the deckle edges. The paper web is taken through a pair of iron draw-rolls, carried by brass bearings, fitted in cast-iron stands; there are two pairs of ripping-knives with bosses, springs, and collars, mounted on turned wrought-iron shafts running in brass bearings carried by cast-iron stands; a wrought-iron leading-roll and carrying brackets fitted with brass bushes; a copper measuring roll counter, geared to indicate up to 10,000 yards, with disengaging apparatus to cease measuring when the paper breaks; a friction-drum 2 feet in diameter, made of wood,

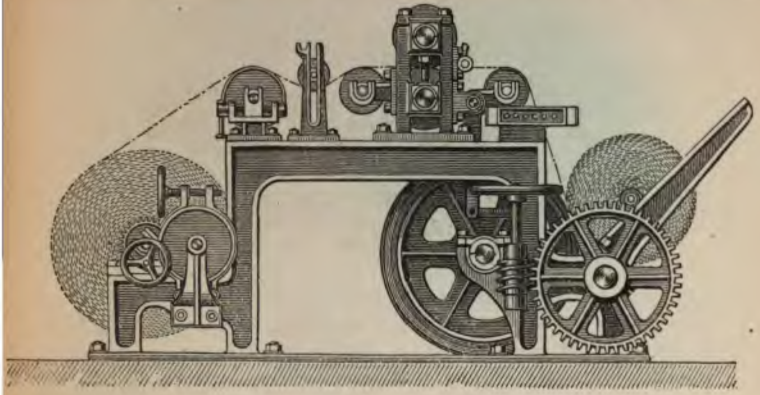


Fig. 47.

mounted on cast-iron rings, and a wrought-iron shaft, all carefully turned and balanced; two cast-iron swivelling arms, with brass sliding bearings to carry the mandrel on which the prepared web is to be wound, with screws, struts, wheels and shaft to regulate the angular pressure of the roll of paper against the wood drum, according to its weight and the quantity of paper.

Cooling and Damping Rolls.—The illustration (Fig. 48) represents an apparatus, constructed by Messrs. Bentley and Jackson, for cooling and damping paper after leaving the drying cylinders and before passing through the calenders. It consists of two brass rolls bored and fitted with cast-iron ends, brass nozzles, and regulating taps, through which the rolls are supplied with a constant flow of water. The rolls are carried by cast-iron standards, fitted with brass steps and cast-iron caps. Jets of steam are blown on each of the rolls from a perforated copper pipe running parallel with, and at a little distance from, the body of the roll. The steam is condensed on the cold surfaces of the brass rolls, and absorbed by the web of paper, which passes around and in contact with their surfaces, and is consequently damped on *both* sides. The perforated steam-pipes are enclosed by copper hoods, to prevent the steam from spreading, and the supply of steam is regulated by ordinary brass valves or cocks. The rolls are geared together by a pair of spur-wheels, and driven by a pulley of suitable diameter.

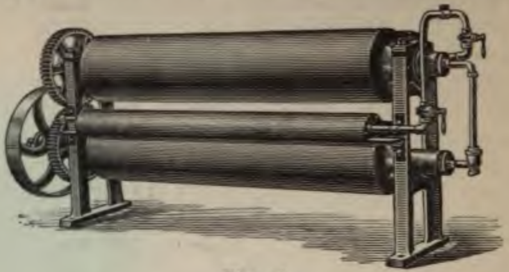


Fig. 48.

Reversing or Plate-glazing Calender.—This machine, which is shown in Figs. 49 and 50, is also made by the firm referred to, and consists of two hammered iron rolls, each about twelve inches in diameter, of any suitable length, carefully turned and carried by strong cast-iron standards, fitted with bell-metal steps. The top roll is provided with setting-down blocks and brasses, com-

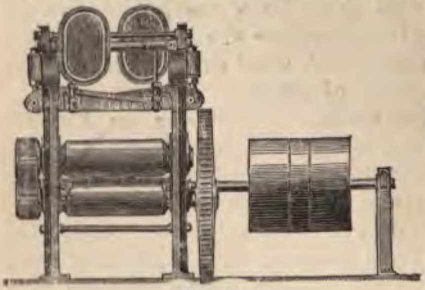


Fig. 49.

pound levers and weights to regulate the pressure required. The two rolls are geared together by strong shrouded wheels, and driven by a strong cast-iron spur-wheel and pinion, a driving-shaft, fast and loose pulleys, carried by cast-iron stands and pedestals fitted with brass steps. The machine is fitted with two metal feed-tables, and a self-acting apparatus for returning the sheets to the rolls, and a handle-lever, slide-bar, and strap-forks for starting and reversing.

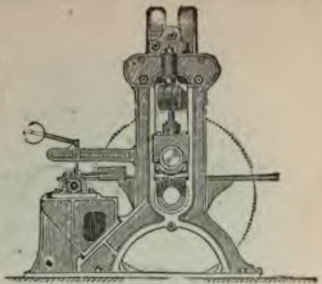


Fig. 50.

Plate-planing Machine.—This machine, which is manufactured by Messrs. Bryan Donkin and Co., of Bermondsey, is shown in Fig. 51. By its aid the plates of rag-engines can be sharpened without being taken to pieces. The slide of the machine is made exactly like the roll-bar planing machine (see below), and is so arranged that it can easily be taken off and used for sharpening roll-bars.

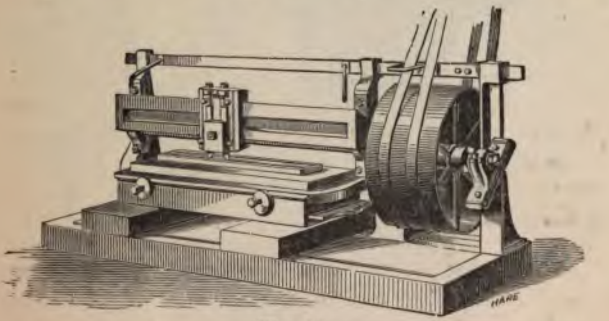


Fig. 51.

Roll-Bar Planing Machine.—In the accompanying engraving (Fig. 52) is shown an apparatus fitted to a

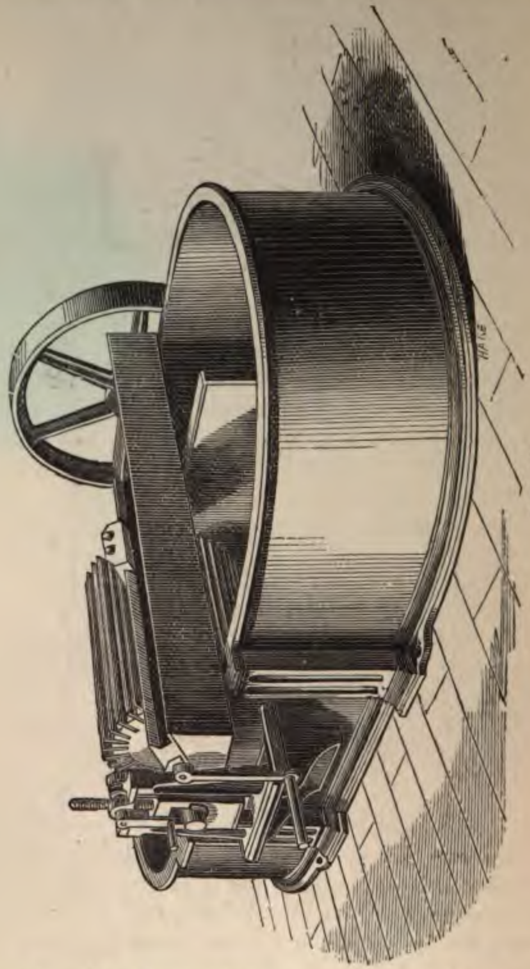


Fig. 52.

rag-engine for sharpening rag-engine roll-bars, and it will be seen that by means of it the operation can be performed without removing the roll from its usual position. The edges of the bars are first planed by a tool supplied by the manufacturers to render the whole cylindrical before sharpening them; the bevelled sides are then planed by suitable tools, two of which accompany the apparatus. This method of sharpening renders the bars uniform in shape, the roll is kept in better working order, and it can be dressed in considerably less time, and at less expense, than can be done by chipping by hand.

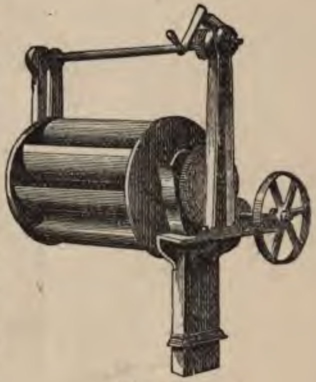


Fig. 53.

Washing-Cylinder for Rag-Engine.—The illustration at Fig. 53 represents the machine as manufactured by Messrs. Bryan Donkin and Co. It is so made that the water is delivered on the driving side of the rag-engine, thus avoiding any trough across the engine, and admitting of the midfeather being thin, as is usual in cast-iron engines. It is all self-contained, and the driving apparatus is wholly on the outside of the engine. The raising and lowering are effected by a worm and worm-wheel, so that the cylinder will stop at any point required.

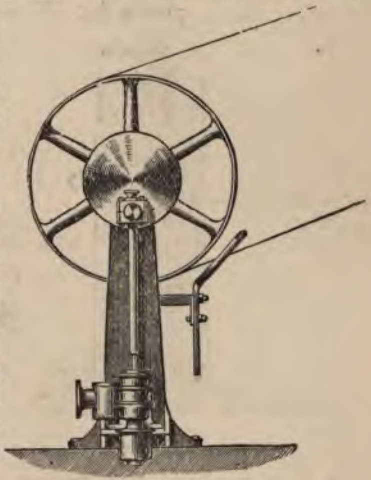


Fig. 54.

Bleach Pump.—In the accompanying engraving (Fig. 54) is shown a pump, manufactured by Bryan Donkin and Co., which is arranged expressly for the purpose of pumping up bleach-liquor. Each pump is all self-contained, and merely requires a drum and strap to drive it. The live and dead riggers upon the pump allow it to be started and stopped at pleasure. "In all paper-mills," say the manufacturers, "the bleach-liquor should be used over and over again, not only to save bleach, which amounts to a considerable sum in the course of a year, but also to keep the paper clean."

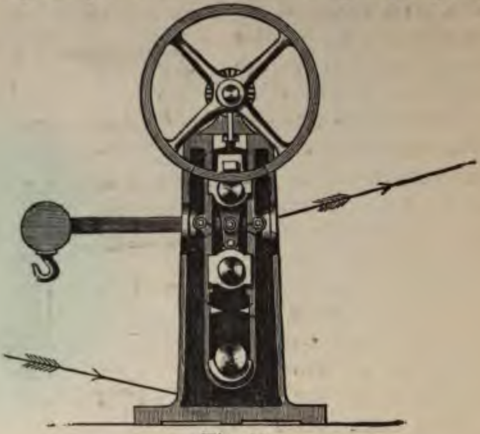


Fig. 55.

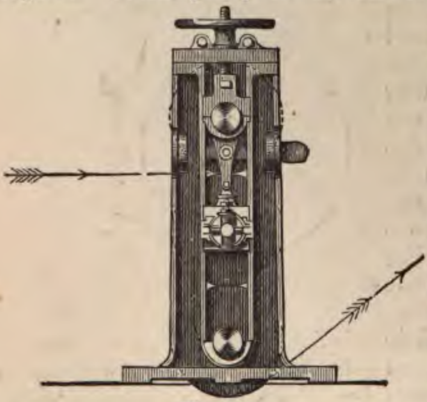
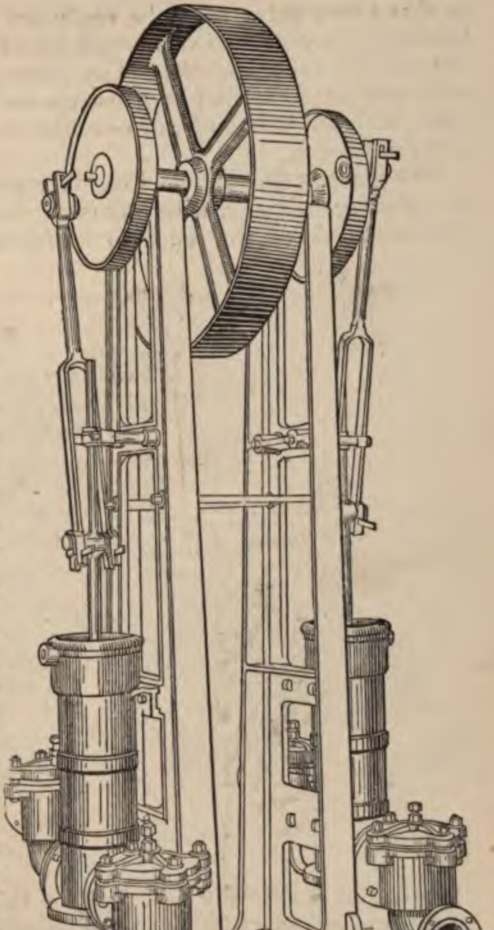


Fig. 56.

Three-Roll Smoothing-Presses.—The engraving (Fig.

55) shows a damp smoothing-press, with rolls for smoothing the paper between the two sections of drying cylinders of a paper-machine. The makers are Messrs. Bryan Donkin and Co. A three-roll smoothing press, for smoothing the paper at the end of a paper-machine, also by the same makers, is shown in Fig. 56.



Back-water Pump.—The engraving (Fig. 57) shows a pair of back or size-water pumps, manufactured by Bertrams, Limited. The barrels are of cast-iron, lined with copper. The suction and discharge valves are each contained in a chamber with covers, so that every valve could be easily got at by simply releasing the cover. The valve-seats are of brass, with brass guards and rubber clacks. The plungers are of brass, with cup-leathers. All is fitted up on a cast-iron sole-plate, with tall standards, disc-cranks, and driving-pulley between frames.

Web-glazing Calender.—Fig. 58 represents Bertrams' web-glazing calender, with steam-engine attached. The illustration shows the machine in front elevation. The steam-engine is specially designed for this class of work, having two cylinders 10 inches in diameter by 16 inches stroke, fitted on a double-hooded sole-plate, with double-throw crank-shaft, fly-wheel, two eccentrics, wrought-iron piston-rods, connecting-rods and valve-rods, steam and exhaust branch pipes with one inlet valve, lubricators,

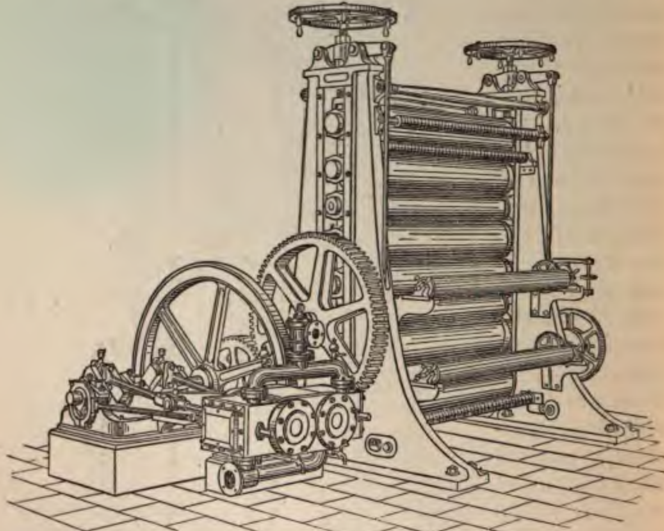


Fig. 58.

and the cylinders cased with teak legging and brass hoops.

Reeling Machine.—One form of reeling machine manufactured by Bertrams, Limited, is shown in Fig. 59, and is used for slitting and re-reeling webs of paper, especially where large webs are requisite for web-calendering, web-printing, and suchlike. The reel of paper from the paper-machine is placed on a sliding-carriage arrangement, the brackets of which are planed and fitted to a planed sole, with wedge or dove-tail corners, and controlled by screws, hand-wheel, etc., so that the reel can quickly and easily be moved forward or backward to suit any unequal reeling that may have taken place on the paper or the machine. A hot cast-iron is provided for mending breaks in the web, and a measuring-roll and counter is also applied. The ma-

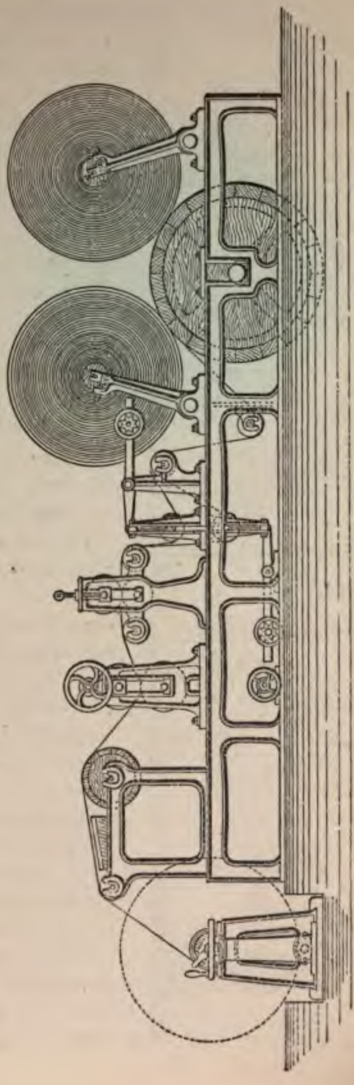


Fig. 59.

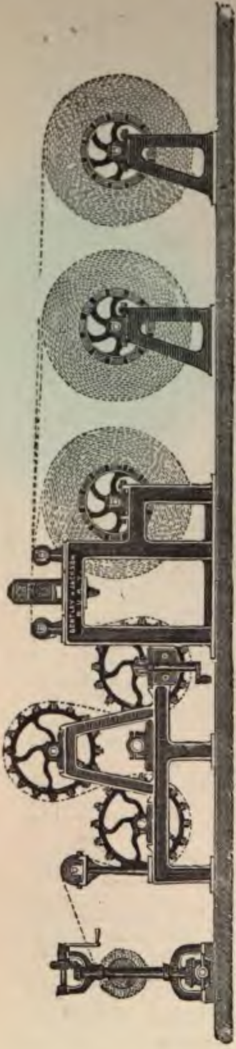


Fig. 60.

chine has an important application of drawing-in or regulating rolls of cast iron, with arrangement of expanding pulley for regulating the tension on the paper. Slitting-knives, regulating, dancing, or leading-rolls, of cast iron, etc., are applied for separating the edges and guiding the webs after they are slit. The reeling is performed by a 3-feet diameter drum, cross-shafts, and arms, to which regulating heads are fitted, so that several webs can be run up at one operation.

Web-Ripping Machine.—This machine, which is manufactured by Messrs. Bentley and Jackson, is shown in Fig. 60, and is constructed to divide webs of paper into two or more widths. It consists of two brass bearings on cast-iron standards, with screw adjustments, a break-pulley and friction-regulator, all mounted on cast-iron slides, movable transversely by means of a screw, geared-wheels, shaft and hand-wheel; a wood guide-roll, about 7 inches diameter, with wrought-iron centres, carried by brass bearings with screw adjustment; three skeleton drums, each 2 feet in diameter, on wrought-iron shafts, carried by brass bearings, and driven by spur-wheels and pinions; two wrought-iron leading-rolls, with brass bearings and cast-iron stands; a pair of strong wrought-iron ripper shafts with circular steel knives, bosses, springs, and collars; cast-iron stands and brass bearings, spur-wheels and driving-pulley; two (or more) changeable wood drums 1 foot 6 inches in diameter, each with wrought-iron shaft and catch-box, carried by brackets fitted with brass steps for easily changing, driven by wrought-iron shafts with pedestals and friction-pulleys, 2 feet in diameter, with regulating screws and lock-nuts, all carried by strong cast-iron framing and standards, and driven by a wrought-iron driving-shaft, with fast and loose driving-pulleys, strap-fork and levers for starting and stopping.

Roeckner's Clarifier.—In this apparatus, of which an illustration is given in Fig. 61, Mr. Roeckner has taken advantage of the fact that if a column of liquid is ascending very slowly and quietly within a vessel, it will not be able to carry up with it the solid particles which it contains, which will gradually fall back and sink to the bottom under the action of gravity, without ever reaching the top of the vessel, provided this be of sufficient height. The illustration shows the arrangement of the apparatus on a small scale; the liquor to be clarified is run into a well or reservoir *b*; into this dip a wrought-iron cylinder *c*, which is open at the lower end, but hermetically closed at the top by means of the casing *d*. From this casing air can be withdrawn through a pipe, *h*, by means of an air-pump *i*. As soon as this is done the liquid will begin to ascend the cylinder *c*, and if the height of this is below that to which the water will rise at the atmospheric pressure (say 25 feet), the liquid will ascend until it fills the cylinder and the casing. Into the pocket at the side of the casing there dips a pipe *g*, which passes out through the opposite side of the casing, descends below the level of the water in the tank, and ends in a discharge-cock. When this cock is opened, the cylinder *c* and the pipe *g* form between them a syphon, of which, however, the descending leg is of very small diameter compared with the ascending leg. In consequence, the liquid will rise in the cylinder *c* very slowly. The sediment it contains will sink back and collect in the bottom of the tank *b*, and clear water will flow out at the outlet. A sludge-cock at the bottom of the tank allows the solid matter to be drawn off at intervals and conveyed to any convenient place for drying, etc.* For drawing clear water from a river, the clarifier would simply be

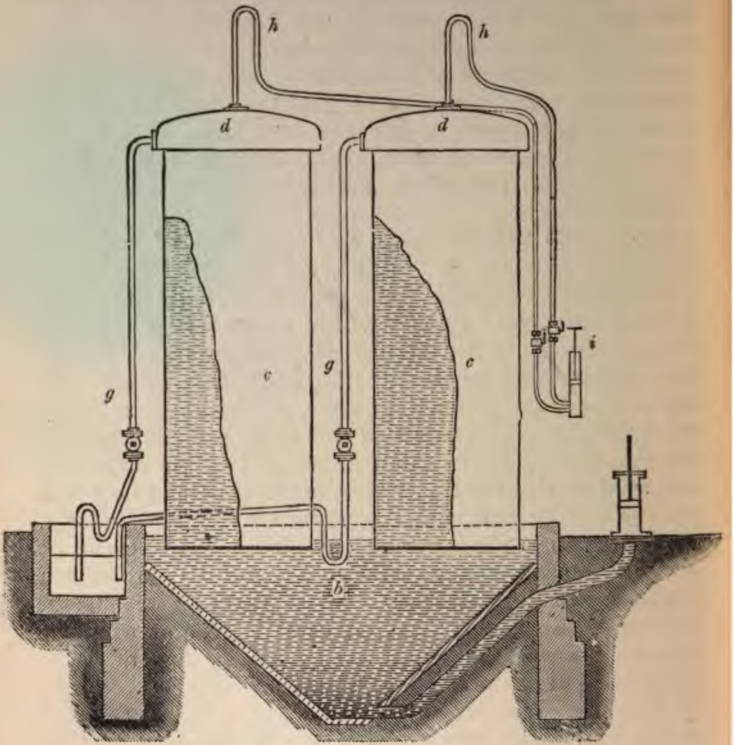


Fig. 61.

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* *Sanitary World*, March 29th, 1884.

placed in the river, dipping 2 or 3 inches into it below the lowest water-level. The clear water will then be drawn through the clarifier, while the heavier matters will fall down and be carried away by the river current. It is stated that this has proved a great advantage to a paper-mill which used a river, and had, prior to its use, been much troubled through the dirt being pumped with the water. The clarifier to receive the waste from paper-machinery, or from washings in the engines, can be placed in any convenient corner, and by its action the water can be re-used, and the otherwise lost fibres collected, without its action ever being stopped.

Marshall's Perfecting Engine.—This engine, a longitudinal section of which is shown in Fig. 62, has been introduced into this country by Messrs. Bentley and Jackson, and is described in *Industries*[*] as follows:—"The machine, which is the invention of Mr. F. Marshall, of Turner's Falls, Mass., U.S.A., is used in one of the processes of paper manufacture, and has for its purpose the more effectual drawing of the pulp fibre, the clearance of knots from the pulp previous to its delivery on to the paper-making machine, and the saving of time in the treatment of the material. As will be seen in the illustration (Fig. 62), the machine consists essentially of a cast-iron conical casing, bored, and fitted with about two hundred elbowed steel knives, G, placed in sections. At the large end of this conical casing is placed a movable disc, also fitted with about two hundred and ten steel knives, F, and capable of adjustment by means of a screw, worm, worm-wheel, and hand-wheel, E. The revolving cone and disc are of cast iron, fitted with straight steel knives firmly keyed upon a hammered iron shaft, and carefully balanced to prevent vibration. The knives of the revolving cone and disc are brought into contact with the stationary knives by means of the hand-wheel E, and the disc-knives can be independently adjusted by means of the hand-wheel C, which actuates a screw on the conical casing by means of the worm and

[*] *Industries*, January 25th, 1889.

worm-wheel shown. The machine is driven by means of a pulley A, and the whole machine is mounted on a cast-iron base-plate. The pulp material enters the engine in the direction indicated by the arrow, B, at the small end of the cone, and is, by the rotary and centrifugal action of the revolving cone, propelled to its large end, and during its passage is reduced to a fine pulp by the action of the knives. It then passes through the knives, F, of the stationary and rotating discs, by which the fibres are further crushed or split up, all knots or strings rubbed out, and the pulp effectually cleared previous to its exit through the passage D." We are informed that the machine is capable of treating from 900lbs. to 1,200lbs. of pulp per hour. The power required to drive it is estimated at from

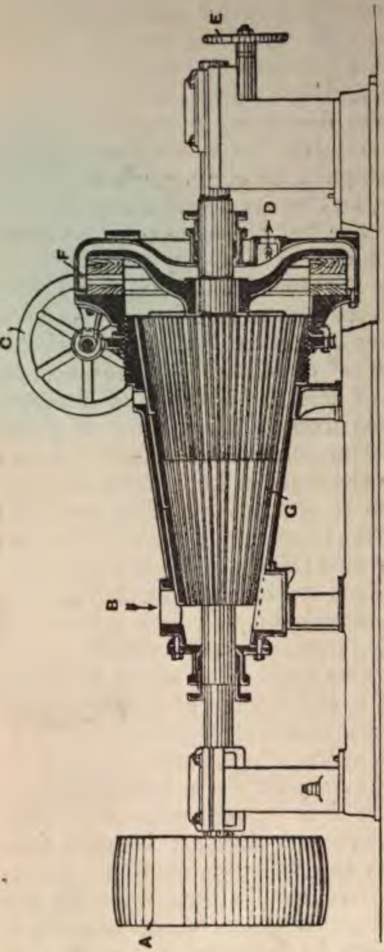

Fig. 62.

40 i.h.p. to 50 i.h.p. when making 300 revolutions per minute. This, however, is dependent on the amount of friction caused between the surfaces of the fixed and revolving knives. The flow space occupied is 12ft. 6in. in length, and 4ft. in width. The perfecting machine, in its complete form, is shown in Fig. 63.

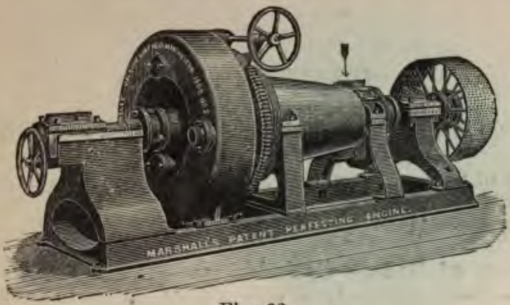
MARSHALL'S PATENT PERFECTING ENGINE.

Fig. 63.

CHAPTER XVIII.

RECOVERY OF SODA FROM SPENT LIQUORS.

Recovery of Soda.—Evaporating Apparatus.—Roeckner's Evaporator.—Porion's Evaporator—American System of Soda Recovery.—Yaryan Evaporator.

Recovery of Soda.—Probably one of the most important improvements in modern paper-making, at least from an economical point of view, is the process of recovering one of the most costly, and at the same time most extensively used, materials employed in the manufacture—soda. While not a great many years since (and in some mills is still the case even now), it was customary to allow the spent soda liquors resulting from the boiling of various fibres to run into the nearest rivers, thus not only wasting a valuable product, but also polluting the streams into which they were allowed to flow, means are now adopted by which a considerable proportion of the soda is recovered and rendered available for further use. The means by which this is effected are various, but all have for their object the expulsion of the water and the destruction of the organic matters dissolved out of the fibrous substances in the process of boiling with caustic soda solutions. One of the main objects of the various methods of recovering the soda from spent liquors is to utilise, as far as practicable, all the heat that is generated from the fuel used, whereby the process of evaporation may be effected in the most economical way possible. The principle upon which the most successful methods are based is that the flame and heat pass over and under a series of evaporating pans, and through side flues, by which time the heat has become thoroughly utilised and exhausted. When all the water has been expelled, the resulting dry mass is ignited and allowed to burn out, when the black ash that remains, which is carbonate of soda, is afterwards dissolved out, and the alkaline liquor causticised with lime in the usual manner. According to Dunbar, 8 cwt. of recovered ash and 4½ cwt. of good lime will produce 900 gallons of caustic ley at 11° Tw. The liquor is then pumped into settling tanks, from which it is delivered to the boilers when required.

Evaporating Apparatus.—An ordinary form of evaporator for the recovery of the soda is shown in Fig. 64. It consists of a chamber A, of the nature of a reverberatory furnace, lined with fire-brick, the bottom of which is slightly hollowed. Above this is a tank B containing the liquor, which is run down into the chamber as required by means of a pipe C, provided with a tap. At one end of the chamber is a furnace D, the flame of which passes through the chamber and over the surface of the liquor lying upon the floor, heating the chamber, evaporating, and at last incinerating, its contents, and at the same time warming the liquor in the tank above, and evaporating some of its water. The products of the combustion in the furnace, and of evaporation, pass by the flue into a chimney, and escape thence into the air. There is a door E in the side of the furnace near the level of the floor of the chamber, and this is opened from time to time to enable

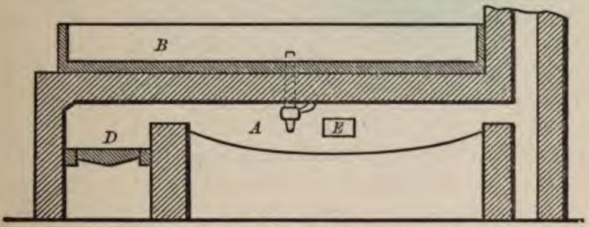

Fig. 64.

the workmen to stir and move about the contents of the chamber, and finally, when the process is sufficiently advanced, to draw out the residue. The first effect produced is the reduction of the liquor to the consistence of tar. Later on, a white crust, which is the incinerated material, forms on the surface, and is drawn on one side by the workmen, so as to allow of fresh crust being formed. When all the charge has become solid it is drawn. The charge is usually withdrawn before the conversion into carbonate is completed; it is then raked out into barrows and placed in a heap, generally in a shed or chamber, open on one side, but sometimes in a closed brick-chamber or den, where the combustion continues for several weeks. The result is the fusion of the material into a grey rocky substance, which consists chiefly of carbonate and silicate of soda.

Various modifications of the esparto evaporator and calciner have, however, been introduced since the recovery of soda has become more general, and are in use at various works, all having for their main object the economising of fuel and the utilising of the waste heat of the fire, which in the old-fashioned calciner goes up the chimney and is lost. The leading principle of all of them is to use the waste heat in concentrating the liquor preparatory to its being run into the part where the calcination is to be effected. This is done by so extending and widening out the flue as to cause the heated air and flame, after they have performed their function in the calcination, to pass over or under their layers of liquor, lying upon shelves or floors in such a way that the liquor shall become more and more concentrated as it approaches the calciner by successive steps or gradations.[*]—*Dr. Ballard.*

Roeckner's Evaporator.—This apparatus, an illustration of which is shown in Fig. 65, is thus described by Dr. Ballard, medical officer of the Local Government Board, who was specially appointed by the board to investigate the effluvium nuisances which arise in connection with certain manufacturing industries. "In this apparatus there is above the calcining floor a series of shelves or shallow pans, alternating in such a manner that the liquor flowing from the tank above into the uppermost of them, flows, after a partial evaporation, over the edge of the shelf into the shelf or shallow pan next below, and in this way from shelf to shelf, still becoming more and more concentrated until it reaches the final floor, over which the flame from the actual fire plays, and where the first part of the calcination is effected. The heated air, in passing to the chimney, passes over each of these shelves in succession, heating them and concentrating the liquor upon them. There is between the lower shelves an arrangement for causing the liquor to pass from the upper to the lower by means of a pipe, instead of its running over the edge. At the top of all is a covered tank, where the temperature of the liquor is raised before it is run into the evaporator. In order to promote the heating of the liquor in this tank, the lower part of the tank is made to communicate by side pipes with tubes passing across the evaporator near the fire, as, for instance, at the bridge and at the further end of the calcining floor. In this way a circulation of liquor is set up which serves to heat the

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[*] "Seventh Annual Report of Local Government Board," 1877-8.

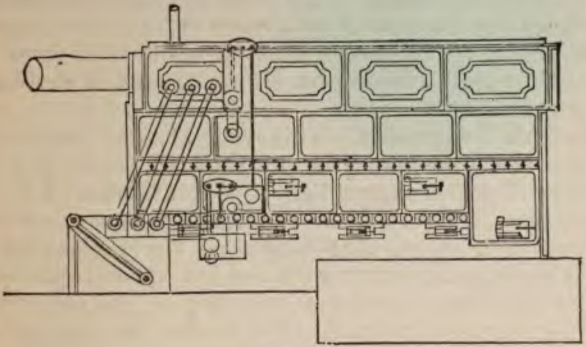

Fig. 65.

liquor in the tank more effectually. A pipe from the top of the tank leads to the chimey-shaft, conducting any vapours into it. As the incinerated crust forms it is raked on one side, and when sufficient of it has accumulated it is drawn to an opening (provided with a damper) at the side or end of the floor, and discharged down this opening into a brick chamber below, which is inclosed by iron doors, and from which a flue conducts the vapours that arise during the final fusion through the fire in such a way as to consume them." By recent improvements Mr. Roeckner has constructed an apparatus for condensing and rendering inoffensive the vapours eliminated from the liquor during its evaporation on the successive shelves of his evaporator.

Porion's Evaporator.—This evaporator and incinerating furnace much resembles in principle an ordinary reverberatory furnace, except that it is provided with paddle agitators, which project the liquid upwards, causing it to descend in a spray, thus increasing the surface of the liquid coming in contact with the hot air and current of smoke traversing the furnace. By this method the expense of fuel is greatly reduced. The residue is in a state of ignition when it is withdrawn from the furnace, and is piled in heaps so that it may burn slowly. When the combustion is complete, the resulting calcined mass is treated with water, and the carbonate of soda formed is afterwards causticised in the usual way. About two-thirds of the soda is thus recovered.

The Yaryan Evaporator.—Mr. Homer T. Yaryan, of Toledo, Ohio, U.S.A., has introduced some important improvements in evaporating apparatus, which have been fully recognised in America, and appear to have been attended with success. The principle involved is that of multiple effects, in which the evaporation takes place while the liquid is flowing through heated coils of pipe or conduits, and in which the vapour is separated from the liquid in a chamber, at the discharge end of the coils, and is conducted to the heating cylinders urrounding the evaporating coils of the next effect, from the first to the last effect. The objects of the invention are: (1) to provide extended vaporising coils or conduits and increased heating surface for each liquid feed supply in the heating cylinders, and provide improved means for feeding the liquid, whereby each set or coil of vaporising tubes will receive a positive and uniform supply of liquid without danger of the feed ducts being clogged by extraneous matter; (2) to positively control the amount of liquid fed by the pump to the evaporating coils, and make it more uniform than heretofore, regardless of the speed of the pump; (3) to provide improved separating chambers at the discharge ends of the vaporising coils so as to better free liquid and solid particles from the vapours; (4) to provide for the successful treatment of the most frothy liquids by causing the vapours carrying solid and liquid particles to pass through catch-all chambers, where they are arrested and precipitated and then returned to the evaporating coils; (5) to secure a more positive flow and circulation of liquid from the evaporating cylinder of one effect to another, under the influence of a better vacuum than heretofore in multiple-effect vacuum evaporating apparatus; (6) to provide for transferring a better concentrated liquid into the separating chamber containing cooler concentrated liquid in direct connection with the condenser and vacuum pump, so as to equalise the temperature of the two liquids, and then draw off both by one tail pump.

The present invention comprises a series of important improvements on an apparatus described by Mr. Yaryan in a former English patent, No. 14,162 (1886), and covers a number of important modifications in construction, whereby improved results are secured. It is only necessary, therefore, to give the details of the new patent, No. 213 (1888), since it embodies the latest improvements which practical working of the apparatus has suggested. In reference to the accompanying illustrations the following details are given: Fig. 66 represents a side elevation of the apparatus; Fig. 67, the front elevation; Fig. 68, a top

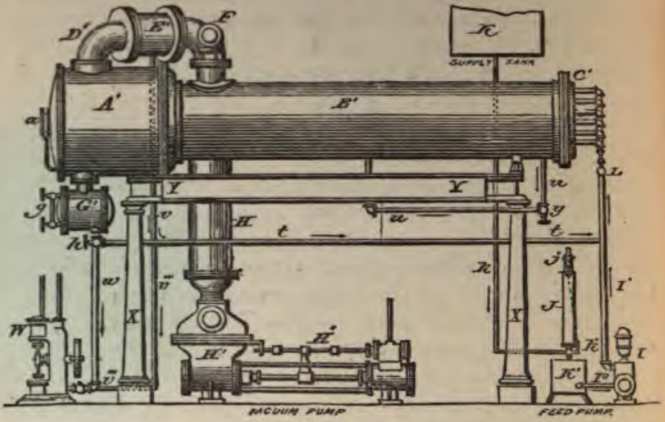

Fig. 66.

plan view; Fig. 69, a vertical section of a cylinder showing

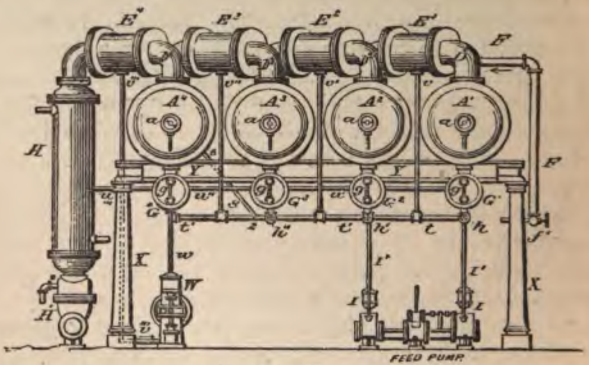

Fig. 67.

the evaporating coils and separating chamber; Fig. 70 is a horizontal section; and Fig. 71, a vertical section of the

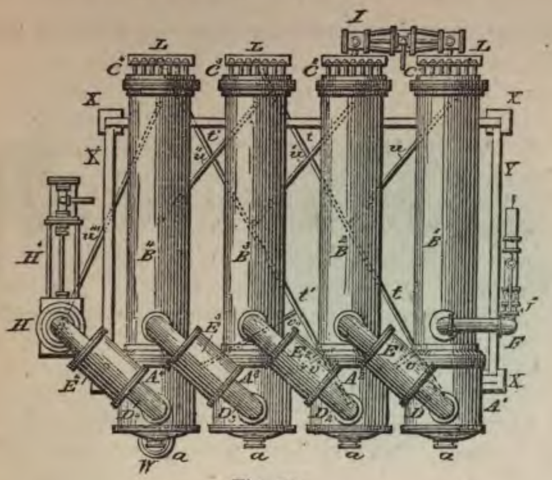

Fig. 68.

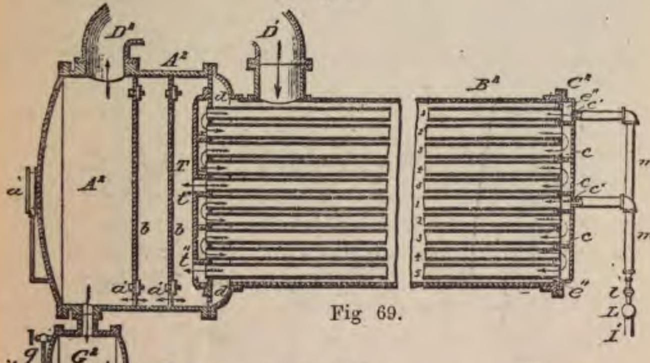

Fig 69.

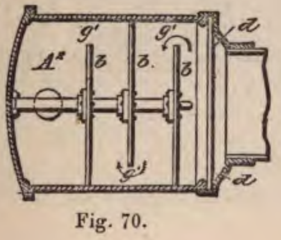

Fig. 70.

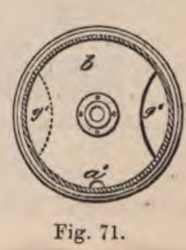

Fig. 71.

effect, with four connected cylinders, but multiple effect apparatus may be constructed with an increased number of cylinders up to ten or twelve. The heating cylinders B^1 B^2 B^3 B^4, containing the evaporating tubes or coils, are preferably arranged in the same horizontal plane, and are provided at the discharge ends of the evaporating coils with separating chambers, A^1 A^2 A^3 A^4, of enlarged diameter, and at the supply ends of the coils with the coils with return bend ends, C^1 C^2 C^3 C^4. From each separating chamber, A^1, A^2, valve pipe D^1 D^2 D^3 leads into the shell of the next heating cylinder, as B^2, B^3, B^4, and vapour pipe D^4 leads from the last separator A^4 to the condenser H, and the vacuum pump H^1. A cylindrical catch-all chamber

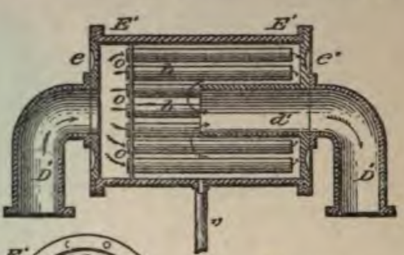

Fig. 78.

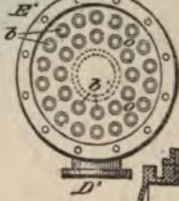

Fig. 79.

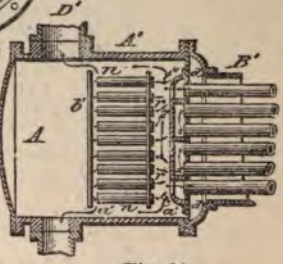

Fig. 80.

E^1, E^2, E^3, E^4, is connected in each vapour pipe between each separator and each successive heating cylinder, as shown in Figs. 66, 67, and 68, and in detail in Fig. 75. Gauge glass and liquid receiving chambers, G^1, G^2, G^3, G^4, connect with the bottom of each separating chamber for receiving the liquid as it is separated from the vapour, and a gauge

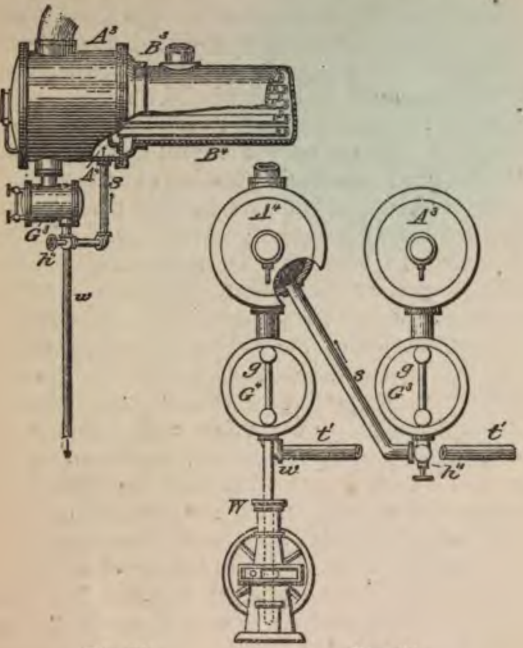

Fig. 81. Fig. 82.

glass g is applied to each of such chambers. Liquid discharge and transfer pipes t, t^1, having valves h, h^1, as best shown in Figs. 66, 68, and 72, lead respectively from chambers G^1, G^2, of the first and second effect to the manifold feed pipes leading into the cylinders B^3, B^4, of the third and fourth effect for the purpose hereafter described. The main steam supply pipe F, having a safety valve *f* and stop valve f^1, Figs. 66, 67, and 68, connects with the heating cylinder B^1 of the first effect. The evaporating tubes 1, 2, 3, 4, 5, are expanded or otherwise secured in the tube sheets *d* and *e*″ at opposite ends of the cylinders, and are properly connected at the ends in sets of five to form coils. The outer rear return-bend head C^1 C^2, etc., are provided on their insides with numerous short intersecting partition plates *c*, forming single and double cells, properly arranged for connecting the evaporating tubes in sets of five, as shown in Figs. 75, 76, 77.

The heads are pierced with holes *c*′ for connecting the liquid supply pipes M of the manifolds L. The inner return-bend head T in the separating chambers are formed like heads C^1 C^2, etc., with intersecting partition plates *x*, and are provided with discharge openings *t*″ for every fifth tube, as shown in Fig. 69. Tube sheet *d* is made of considerably larger diameter than cylinders B^1 B^2, etc., and acts as a vibrating diaphragm, to accommodate the expansion and contraction of the tubes. The separating chambers may be constructed with dash plates *b b*, two or more in number, having openings *g*′ *g*′ alternately upon opposite sides for the passage of vapour, and opening *a*′ at the bottom for the passage of liquid, as shown in Fig. 80. Here a tube sheet *z* is provided near the openings of the evaporating tubes, and in such sheet are set numerous small horizontal tubes *n*, which discharge against a vertical arresting plate *b*′ set near their open ends. Water and solid matter are impelled against the plate and thereby arrested and caused to flow down to the bottom of the chamber. The liquid feed apparatus consists of a supply tank K, stand-pipe J, feed box K^1, double pump I, manifold L, and connecting pipes and valves. The liquid to be evaporated flows from tank K, through pipe *k*, to stand-pipe J and box K^1, the flow being constant and uniform, and of the desired quantity, by means of a valve *k*′ having a lever handle *r*′ which is connected by a cord or chain passing over a pulley *j* with float *q* in stand-pipe J. The valve opening in pipe *k* being properly adjusted by means of the float, etc., the liquid is admitted to the stand-pipe J while the column of liquid is automatically maintained at any desired height and pressure regardless of the quantity in the supply tank, by means of the float *q*, which, as it rises, tends to close valve *k′*, and as it falls, to open the valve. From the bottom of the stand-pipe J, nozzle *j′* discharges a constant and uniform stream of liquid into feed box K^1. The suction pipe I″ of pump I extends into box K^1, where it terminates in a turned-down nozzle provided with valve *i* having a lever handle and float *z*. As a given amount of liquid is constantly running into the box, should the pump run too fast the float lowers, partially closing the valve and lessening the amount of liquid drawn at each stroke of the pump, and preventing air from being drawn in, since the end of the suction pipe is always sealed by the liquid. The liquid is forced by pump I into the manifolds L, from which it flows through the contracted ducts *l* into the enlarged feed pipes *m*, as shown in Figs. 73 and 74. Ducts *l* are of about one-half inch diameter, and the upper and lower sections thereof are connected by a union coupling, one portion of which *l′* has a reducer with opening one-quarter inch diameter, more or less, according to the amount of liquid it is desired to feed.

The catch-all chambers E^1 E^2, etc., Figs. 66, 78, and 79, are provided each at its inlet end *e*, with tube sheet *o* extending across its diameter a short distance in front of the opening of vapour pipe D^1, and in such sheet are fixed numerous longitudinal tubes *p* extending to near the opposite head *e′*, so that vapours carrying watery or solid particles are impelled against the head and arrested. Liquid and solid matter, arrested in the catch-all chambers, flow through pipes *v v′ v″* down into the fluid transfer pipe *t t′* (Figs. 67, 68, and 72), and thence into the evaporating coils and through pipe *v‴* directly to the tail pump W, Fig. 67. By use of the catch-all chambers the most frothy liquids can be readily and economically managed. A liquid transfer pipe s, having a valve h'', leads directly from receiving chamber G^3 of the third effect to the separating chamber A^4 of the fourth effect, the latent heat being carried off in the vapours drawn by the vacuum pump H^1 into the chamber H, and the finished liquid of both effects is drawn off through pipe w by one and the same tail pipe pump W. The water of condensation accumulating in the heating cylinders B^1 B^2, etc., is transferred from one to the other through connecting pipes $u\,u'\,u''$ having valves y, shown in Figs. 66, 67, and 68; and finally from cylinder B^4 through pipe u''' directly into condenser H. The specification of the patent, which those interested will do well to consult, next describes the operation of the apparatus.

American System of Soda Recovery.—Mr. Congdon gives an exhaustive description* of the method of recovering soda in the United States, from whose interesting paper we extract the following:—The spent liquors are delivered to the Yaryan evaporator from the pans at a density of 6° to 7° B. at 130° F. Here they are concentrated to 34° to 42° at 140° F. At this density they are fed into furnaces of a reverberatory type, where they are burnt to a cherry-red heat, and the ash then raked out. This ash, which averages 50 per cent. of soda, is weighed in iron barrows on suitable scales, and wheeled into the leaching-room for lixiviation. The system of leaching, as it is termed in the States, is conducted as follows:—Iron tanks are used, with suitable piping, that allows pumping from one tank to another, and also to pump from any one of them up to the causticising tanks in the alkali-room. There is also a water-line by which water may be pumped into any of the tanks, and there is a spout used in washing away the black ash sludge. The leaching-tanks have false bottoms of 2in. by 2in. stuff, placed crosswise, over which is a layer of gravel, on which lies a layer of straw, by which the liquor is filtered. The gravel is removed every few days, and the straw with every charge. When one of the tanks is filled with black ash, it is "wet down" with the stored liquor (the strongest of the stored weak liquors), and also with the strongest weak liquors from the tanks, and with weak liquors obtained from these tanks by pumping water upon them and keeping them full. This is all pumped up to the causticising-tank until the strength is reduced to 2° or 1½° B. The remaining liquor is then drained into a tank known as the "clear-liquor" tank, owing to there being no black ash in it. The liquor from the next weakest pan is then pumped upon the pan containing the black ash, and the next weakest liquor pumped upon this. The weaker pans are then in succession pumped upon the stronger, and the water pumped upon these, and thus a very perfect washing is obtained. The sludge left behind is nothing but charcoal, with a slight trace of carbonate of soda. Mr. Congdon illustrates the above system thus. The tanks stand as follows:—

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* School of Mines *Quarterly Journal of Applied Science*, January, 1889, New York.

No. 1. Clear liquor, 1° to 2° B. (strongest).
No. 2. Black ash sludge (weaker than No. 3).
No. 3. Black ash, after sending up to causticising-tank (strongest sludge).
No. 4. Fresh black ash.
No. 5. Weaker than No. 2 (sludge only).
No. 6. Weaker than No. 5 (sludge and weakest liquor).

The method of procedure is as follows:—

Liquor from No. 3 drained into No. 1 (now full).
No. 6 pumped on to No. 2 (No. 6 sludge thrown away).
Liquor from No. 2 drained upon No. 3.
Water put on No. 5.
No. 5 pumped upon No. 2 (No. 5 sludge thrown away).

The black ash is treated thus:—

No. 4, full of black ash, is wet down with Nos. 1, 2, and 3, and pumped up to the causticising-tank.

Water is pumped out to Nos. 2 and 3, and then drained upon No. 4, the liquor still being pumped up from No. 4 while the water is being pumped upon Nos. 2 and 3, which are kept full. This is continued until the liquor tests only 2° to 1° B.

No. 4 is now drained upon No. 1.

No. 3 pumped upon No. 4, and this drained into No. 1 (now full).

No. 3 pumped upon No. 5.

Water pumped upon No. 2 (No. 2 the next to be thrown away).

No. 5 is by this time full of fresh black ash, and the same process is carried out with No. 4.

CHAPTER XIX.

DETERMINING THE REAL VALUE OR PERCENTAGE OF COMMERCIAL SODAS, CHLORIDE OF LIME, ETC.

Examination of Commercial Sodas.—Mohr's Alkalimeter.—Preparation of the Test Acid.—Sampling Alkalies.—The Assay.—Estimation of Chlorine in Bleaching Powder.—Fresenius' Method.—Gay-Lussac's Method.—The Test Liquor.—Testing the Sample.—Estimation of Alumina in Alum Cake, etc.

In a manufacture such as paper-making, which involves the consumption of enormous quantities of materials of variable quality, as soda ash, caustic soda, and bleaching powder, for example, it will be readily seen that some means should be at the command of the consumer who does not avail himself of the services of a practical chemist at his works, by which he can ascertain the *actual* value of the various substances he uses. An art which, up to a certain point in its progress, is mainly a chemical operation, it would undoubtedly be more safely and economically conducted when supervised by persons well acquainted with chemical principles and reactions, and less dependent upon individual judgment, than is, perhaps, too frequently the case. Under such supervision more perfect uniformity of results—a consideration of the greatest importance in a manufacture of this kind—would be ensured.

Examination of Commercial Sodas.—The methods of determining the percentage of real alkali in the commercial products which have received the name of *Alkalimetry* are fortunately of a simple character, and such as a person of ordinary intelligence and skill can readily manipulate and render thoroughly reliable by exerting the necessary care. He must, however, be provided with a few indispensable appliances, which will be described, and with these he should make several trials upon various samples until he finds that his results are uniform and his manipulation easy and reliable. He will require a chemical balance,* capable of weighing to the tenth of a grain; a few glass "beakers" (Fig. 83) of various sizes, capable of holding from four to eight or ten ounces of fluid; several glass stirrers; a bottle of litmus solution, made by dissolving litmus in hot water; books of litmus and turmeric papers; and several glass flasks (Fig. 84) of various sizes, capable of holding from four to eight ounces. Besides these accessories, certain measuring instruments, termed *alkalimeters* or *burettes*, are employed, of which either of the two following may be employed. These instruments are of glass, and hold up to 0 or zero exactly 1,000 grains. The scale is graduated in a hundred divisions, which are again subdivided into tenths. Bink's burette is shown in Fig. 85, and Mohr's burette in Fig. 86. The latter, being provided with a stand, enables the operator to add the test

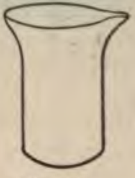

Fig. 83.

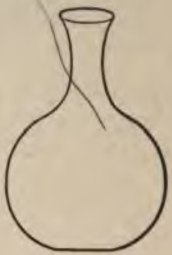

Fig. 84.

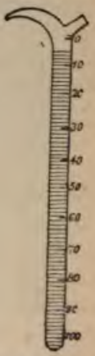

Fig. 85.

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* These balances may be obtained from Mr. Oertling, Coppice Row, London, or of any philosophical intsrument maker.

liquor—with which the burette is charged—drop by drop, when the alkaline solution to be tested is near the point of saturation, without engaging the hands.

Mohr's Alkalimeter.—This useful instrument (Fig. 86) and the method of using it is thus described by Mohr:—"I have succeeded in substituting for expensive glass stop-cocks an arrangement which may be constructed by any person with ease, which remains absolutely air and water-tight for an indefinite period, which may be opened and regulated at will by the pressure of the fingers, and which costs almost nothing. It consists of a small piece of vulcanized indiarubber tube, which is closed by a clamp of brass wire (Fig. 87). The ends of this clamp, which I call a pressure-cock, are bent laterally at right angles in opposite directions and furnished with knobs, so that when both ends are pressed the clamp is opened, and a single drop or a continuous current of liquid may be allowed to escape at pleasure. The measuring-tube is a straight glass cylinder, as uniform as possible, graduated to 0·2 or 0·1 cubic centimetres, and somewhat contracted at its lower end, so as to fit into the indiarubber tube. A small piece of glass tube inserted below the pressure-cock forms the spout. The pressure-cock has the advantage of not leaking, for it closes itself when the pressure of the fingers is removed. The measure, furnished with the pressure-cock,

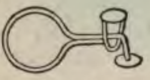

Fig. 87.

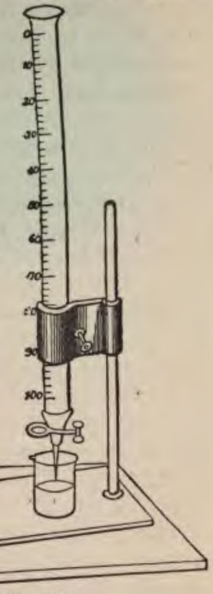

Fig. 86.

is fastened upon an appropriate stand, which can be placed at any required height. When used, it is filled above the zero point with test liquor, the cock opened for an instant, so as to let the air escape from the spout, and the level of the solution is then adjusted. This is done by bringing the eye level with the zero point, and applying a gentle pressure to the cock until the liquid has sunk so low that the inferior curve of the liquid touches the graduation like the circle of a tangent; the cock is then closed, and at the same moment the liquid remains at zero, and continues to do so for weeks if evaporation is prevented. The test-measure being normally filled, the experiment may be commenced; this is done sitting, while the filling of the measure is done standing.

"The weighed sample of alkali is first placed in a beaker-glass, and the test-liquor is allowed to flow into it by gently pressing the cock. Both hands are set at liberty, for when the pressure-cock is released it closes of itself. The volumetric[*] operation may be interrupted at pleasure, in order to heat the liquid, shake it, or do whatever else may be required. The quantity of liquid used may be read off at any moment, and in repeating an experiment, the limit of the quantity used before may be approached so near that the further addition of liquid may be made drop by drop." The test-acid to be used *volumetrically*—that is, with the alkalimeter, has a specific gravity of 1·032 at 60° F., and 1,000 grains by measure contain exactly 40 grains of real or anhydrous (that is, without water) sulphuric acid.

The chemical principles involved in the process of alkali-testing may be thus briefly stated:—According to the laws of chemical combination defined by the atomic theory of Dalton, all substances combine in *definite* proportions or "equivalents"; thus, 1 part by weight of *hydrogen* combines with 8 parts by weight of *oxygen* to form water.

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[*] There are two principal methods of analysing or assaying alkalies by means of the test-acid, namely, *volumetric*, or by volume, and *gravimetric*, or by weight, in which a specific gravity bottle, capable of holding exactly 1,000 grains of distilled water, is used.

The equivalent number of hydrogen, therefore, is 1, and of oxygen 8, and that of water 9. Again, 3 equivalents of oxygen combine with 1 equivalent of sulphur (16) to form sulphuric acid; thus, sulphur 16, oxygen 24, equals anhydrous sulphuric acid 40; therefore 40 is the *equivalent* or combining number of this acid, and it cannot be made to unite with alkalies or other bases in any other proportion. For example, 40 *grains* by weight of *pure* sulphuric acid will neutralise exactly 53 grains of *dried carbonate of soda*, 31 grains of *pure anhydrous soda*, or 40 grains of *hydrate of soda* (caustic soda). This being so, it is only necessary to have exactly 40 grains of *real* sulphuric acid in 1,000 grains of water to form a *test-acid*, which, when employed to neutralise an alkaline solution, will show, by the proportion of dilute acid used to saturate the alkali, the absolute percentage present in the sample.

Preparation of the Test-Acid or Standard Solution.—As there is some trouble involved in the preparation of the test-liquor, it is advisable to prepare a sufficient quantity at a time to last for many operations. It may be readily made by mixing 1 part of concentrated sulphuric acid with 11 or 12 parts of *distilled water*, the mixture being made in what is termed a "Winchester" bottle, which holds rather more than half a gallon, and is provided with a glass stopper. The acid solution must be *adjusted* or brought to the proper strength after it has cooled down to 60° F.; and it should be *faintly tinged* with litmus, which will give it a pinkish hue. The acid, to be of the proper strength, should *exactly* neutralise 53 grains of pure carbonate of soda, previously calcined at a red heat, or 31 grains of pure anhydrous soda. To prepare the anhydrous carbonate of soda, a few crystals of carbonate of soda are placed in a Berlin porcelain crucible, and this must be heated over a spirit-lamp or Bunsen burner. When all the water of crystallisation has become expelled, the calcination is continued until the mass is at a bright red heat, when the vessel may be allowed to cool. 53

grains of the calcined carbonate are now to be carefully weighed, and next dissolved in a glass beaker, in about 2 ounces of distilled water. The alkalimeter is now to be charged with the test-acid to the level of zero, and (if Mohr's burette be used) the beaker containing the alkaline solution is to be placed upon the stand immediately beneath the exit-tube. Now press the knobs of the pressure-cock, and allow a portion of the liquor to flow into the beaker. When the effervescence which immediately sets up subsides, make further additions of the test-liquor from time to time, until the effervescence becomes sluggish, at which period the acid must be added with greater caution. When the solution approaches saturation it acquires a purplish tint (due to the litmus with which the acid is tinged), which it retains until the point of saturation is reached, when it suddenly changes to a pink colour. After each addition of the acid the solution should be stirred with a thin and clean glass rod; and before the final change from purple to pink, the end of the glass rod should be applied to a strip of blue litmus paper, when, if the moistened spot touched assumes a red colour, the saturation is complete; if, on the contrary, the paper is unchanged, or has a violet or reddish hue, add the test-liquor, one or two drops at a time, with continued stirring, until a drop of the solution applied with a glass rod reddens litmus paper, when the saturation is finished. If any test-liquor remain in the burette, this indicates that there is excess of acid in the test-liquor; consequently more distilled water must be added to the bulk, the burette emptied and refilled with the reduced liquor, and another 53 grains of anhydrous carbonate of soda treated as before, until 1,000 grains of the acid liquor *exactly* neutralise the solution. Should the whole contents of the burette in the first trial be used before saturation is complete, a little more sulphuric acid must be put into the Winchester or test-acid bottle, and a 53-grain solution of carbonate of soda treated as before. A very little practice will enable the operator to adjust his test-liquor with perfect accuracy; and, to prevent mistakes, the bottle should be labelled "Test-acid," and always be kept closed by its stopper.

Sampling Alkalies.—Soda-ash of commerce is usually packed in wooden casks, and in order to obtain a fair average sample from a large number of these casks, which may represent one consignment, it is important to take small samples, as near the centre of each cask as possible, from as many of the casks as time will permit. Each sample, as drawn from the cask, should be at once placed in a rather wide-mouthed bottle furnished with a well-fitting cork. Each sample should be numbered and marked with the brand which distinguishes the cask from which it was taken. The duty of sampling should be placed in the hands of a person of known integrity and intelligence.

When about to test a sample of soda-ash, the contents of the bottle should first be emptied upon a sheet of dry paper, and the larger lumps then crushed to reduce the whole to a coarse powder, and this must be done as quickly as possible to prevent absorption of moisture from the atmosphere. 100 grains of the alkali must now be accurately weighed and put into a glass flask (Fig. 84), and the remainder of the alkali returned to the bottle and the vessel securely corked. About half an ounce of distilled water is then to be put into the flask and gentle heat applied, with an occasional shaking, until the alkali is all dissolved. The flask is then to be set aside for a few minutes, until any insoluble matter present has subsided, when the clear liquor is to be carefully poured into a beaker glass; the sediment must be washed several times with small quantities of distilled water, and the washings added to the solution in the beaker. This washing is of great importance and must be performed several times, or until the last washing liquor produces no effect upon yellow turmeric paper, which even slight traces of alkali will turn a brown colour. So long as this brown tint is given to the turmeric paper the presence of alkali is assured, and the washing must be continued. It is important, after each washing, to pour off the last drop of the liquor above the sediment, by which the operation is more effectual, and is effected with less water than when this precaution is not observed. In order to ensure perfect accuracy in the result, every particle of the washings must be added to the contents of the beaker-glass in which the assay is to be made.

The Assay.—The alkalimeter is first to be filled with the test-acid exactly to the line 0 or zero of the scale as described, and the beaker containing the solution to be tested then placed immediately beneath the dropping tube of the instrument; a thin glass rod should be placed in the beaker as a stirrer. The acid liquor is then allowed to flow gradually into the alkaline solution (which should be repeatedly stirred with the glass rod), by pressing the knobs of the pressure-cock, until the solution assumes a purple tint, which it will retain until the exact point of saturation has been arrived at, when, as before stated, it will suddenly change to a pink colour. Before the latter stage is reached the beaker should be placed over a spirit lamp or Bunsen burner, and the liquid heated to expel the carbonic acid which is evolved, and partly absorbed by the solution during the process of saturation. When the neutralisation is complete, the alkalimeter is allowed to repose for a few moments, so that the acid liquor may drain from the interior of the glass tube into the bulk of the fluid, and the quantity of test-acid used is then determined by reading off the number of divisions of the alkalimeter that have been exhausted, every one of which represents $\frac{1}{100}$th part, or 1 per cent. of *alkali*, whenever the *equivalent weight* is taken for assay. Every $\frac{1}{10}$th part of an alkalimeter division represents $\frac{1}{10}$th of 1 per cent., and the result is thus obtained without the necessity of any calculation. The following table shows the *equivalent* or combining proportions of soda with 40 grains of real (that is, anhydrous) sulphuric acid:—

40 grains of sulphuric acid . . . 1,000 grains of dilute sulphuric acid (sp. gr. 1·033) . . . 1,000 grains of dilute sulphuric acid (water-grain measure) sp. gr. 1·032	Are equivalent to	31 grains soda (anhydrous). 40 grains hydrate of soda (pure caustic soda). 53 grains carbonate of soda (anhydrous). 143 grains crystallized carbonate of soda.

Mr. Arnot recommends the following method for alkali testing: "The sample, which should be a fair average of the drum or cask from which it is drawn, should, in the case of caustic soda, be quickly crushed into small fragments, and returned to the stoppered bottle in which it was collected for testing. It need not be finely ground, and, indeed, should not be, as it very readily attracts moisture from the air. The contents of the drum are usually pretty uniform, and the crushing recommended will give the operator a sample quite fit to work upon. Samples of soda-ash and soda crystals will, of course, be fairly representative of the casks from which they are drawn. One hundred grains of the prepared sample must be weighed out upon a watch-glass or slip of glazed paper, and transferred to a porcelain basin, with at least half a pint of boiling water. The watch-glass is preferable for caustic soda, and the weighing in the case of that agent must be done expeditiously. While the sample is dissolving the burette will be charged with the standard acid. To the soda solution a few drops of solution of litmus, sufficient to colour it distinctly, will be added. The acid will then be run into the blue soda liquor; at first, within reasonable limits, this may done rapidly, but towards the close of the operation the acid must be added cautiously, and the solution kept well stirred. In the case of caustic, when the blue has distinctly changed to red, the operation may be considered completed, and the measures may be read off the burette; and this is, without calculation, the result required. When the soda in the sample is a carbonate, the blue colour of the litmus will be changed to pink before all the soda is neutralised, owing to a portion of the liberated carbonic acid remaining in the solution; this must be eliminated by placing the basin over a Bunsen burner and boiling the solution. The blue colour will thus be restored, and more acid must be added, repeating the boiling from time to time, until the red colour becomes permanent. It is sometimes necessary to filter the soda solution before testing; this applies specially the determination of chlorine in bleaching powders, and is conducted as follows:—

The Test-liquor.—This is prepared by dissolving 100 grains of *pure* arsenious acid in about 4 ounces of pure hydrochloric acid, and the solution is to be diluted with water until, on being poured into a graduated 10,000 grains measure-glass, it occupies the volume of 700 grains measure marked on the scale. Each 1,000 grains measure of this liquid now contains 14·29 grains of arsenious acid, corresponding to 10 grains of chlorine, or $\frac{1}{10}$ grain of chlorine for every division or degree of the scale of the chlorimeter, for which purpose a Mohr's burette of the above capacity may be used, or a graduated tube of the form shown in Fig. 85 may be employed.

Testing the Sample.—100 grains of the chloride of lime to be tested are next dissolved in water, and poured into a tube graduated up to 2,000 grains measure. The whole must be well shaken in order to obtain a uniformly turbid solution, and half of it (1,000 grains measure) transferred to a graduated chlorimeter, which is, therefore, thus filled up to 0°, or the zero of the scale, and contains exactly 50 grains of the chloride of lime under examination, whilst each degree or division of the scale contains only $\frac{1}{2}$ grain. 1,000 grains measure of the arsenious acid test-liquor are now poured into a glass beaker, and a few drops of a solution of sulphate of indigo added, in order to impart a faint, but distinct, blue colour to it; the glass is then to be shaken so as to give a circular movement to the liquid, and whilst it is whirling round the chloride of lime solution from the chlorimeter is gradually and cautiously added until the blue tinge given to the arsenious acid test-liquor is destroyed, care being taken to stir the mixture well with a glass rod during the whole process, and to stop as soon as the decoloration is complete. We will assume that in order to destroy the blue colour of 1,000 grains measure of the arsenious acid test-liquor 90 divisions or degrees of the chloride of lime solution have been employed. These 90 divisions, therefore, contained the 10 grains of chlorine required to destroy the colour of the test solution; and since each division represents ½ grain of chloride of lime, 45 grains of chloride of lime (10 grains of chlorine) were present in the 90 divisions so employed, from which the percentage strength may be ascertained:—

For 45 : 10 :: 100 : 22·22.

The chloride of lime examined, therefore, contained 22¼ per cent. (nearly) of chlorine. This method is extremely simple and trustworthy when properly employed, but to ensure accuracy certain precautions must be adopted. Instead of pouring the test liquor into the solution of the sample (as in alkalimetry), the solution of the sample must be poured into the test-liquor. If the contrary plan were adopted the hydrochloric acid of the test-liquor would liberate chlorine gas so fast that much would be lost, and the result rendered incorrect. By pouring, on the contrary, the chloride of lime solution into the arsenious acid solution the chlorine is disengaged in small portions at a time, and meets with an abundance of arsenious acid to react on. The mixture of chloride of lime should also be employed turbid.

Estimation of Alumina in Alum Cake, etc.—Mr. Rowland Williams, F.C.S., in a paper read before the Chemical Society in June, 1888, describes a method of estimating the alumina in alums, alum cakes, and sulphate of alumina, by which he obtained more accurate results than are obtained by the ordinary ammonia method of estimation. After pointing out several objections to the method of precipitating the alumina by ammonia, he proceeds:—"There is another method for the estimation of alumina which is not so well known as the above. This is by means of sodium thiosulphate. Having had a very extensive and successful experience of this process, I can recommend it with confidence. Considerable practice is, however, necessary in order to secure good results, as certain conditions must be carefully attended to, otherwise the precipitation will be incomplete. The estimation is made in a moderately dilute solution. In the case of alum cake and sulphate of alumina I dissolve 400 grains in water, filter, dilute to 10,000 grains. I use 1,000 grains of this solution (equal to 40 grains of the sample) for estimating the alumina. If any free acid is present it is neutralised by a few drops of carbonate of soda solution, and the whole diluted to about 8 ounces measure. A large quantity of crystallized thiosulphate of soda is then added, and the liquid boiled for at least half-an-hour, constantly replacing the water lost by evaporation. By the end of that time all the alumina will be precipitated in a finely-divided form, along with more or less free sulphur. The precipitate is then filtered off and washed well with boiling water. The filtration and washing take place very rapidly, and may generally be accomplished in about twenty minutes, this being a great saving of time in comparison with the long and tedious washing by decantation, which is necessary in the case of gelatinous alumina. Before filtration, it is advisable to add a drop or two of carbonate of soda solution, lest the liquid should have become slightly acid during boiling."

CHAPTER XX.

USEFUL NOTES AND TABLES.

Preparation of Lakes.—Brazil-wood Lake.—Cochineal Lake.—Lac Lake. —Madder Lake.—Orange Lake.—Yellow Lake.—Artificial Ultramarine.—Twaddell's Hydrometer.—Dalton's Table showing the proportion of Dry Soda in Leys of Different Densities.—Table of Strength of Caustic Soda Solutions at 59° F.—Table showing the Specific Gravity corresponding with the degrees of Baumé's Hydrometer.—Table of Boiling Points of Alkaline Leys.—Table showing the Quantity of Caustic Soda in Leys of Different Densities.—Table showing the Quantity of Bleaching Liquid at 6° Twaddell required to be added to Weaker Liquor to raise it to the given Strength.—Comparative French and English Thermometer Scales.—Weights and Measures of the Metrical System.—Table of French Weights and Measures.—List of Works relating to Paper Manufacture.

Preparation of Lakes.—These are prepared by either of the following processes:—1. By adding a solution of alum, either alone or partly saturated with carbonate of potassa, to a filtered infusion or decoction of the colouring substance, and after agitation precipitating the mixture with a solution of carbonate of potash ("salt of tartar"). 2. By precipitating a decoction or infusion of the colouring substance made with a weak alkaline ley, by adding a solution of alum. 3. By agitating recently precipitated alumina with a solution of the colouring matter, prepared as before, until the liquid is nearly discoloured, or the alumina acquires a sufficiently dark tint. The first method is usually employed for aciduous solutions of colouring matter, or for those whose tint is injured by alkalies; the second for those that are brightened, or at least uninjured, by alkalies; the third, those colouring matters that have a great affinity for gelatinous alumina, and readily combine with it by mere agitation. By attention to these general rules, lakes may be prepared from almost all animal and vegetable colouring substances that yield their colour to water, many of which will be found to possess great beauty and permanence.

The precise process adapted to each particular substance may be easily ascertained by taking a few drops of its infusion or decoction, and observing the effects of alkalies and acids on the colour.

The quantity of alum or of alumina employed should be nearly sufficient to decolour the dye-liquor, and the quantity of carbonate of potassa should be so proportioned to the alum as to exactly precipitate the alumina, without leaving free or carbonated alkali in the liquid. The first portion of the precipitate has the deepest colour, and the shade gradually becomes paler as the operation proceeds.

A beautiful "tone" of violet, red, and even purple may be communicated to the colouring matter of cochineal by the addition of perchloride of tin; the addition of arseniate of potassa (neutral arsenical salt) in like manner gives shades which may be sought for in vain with alum or alumina. After the lake is precipitated it must be carefully collected, washed with cold distilled water, or the purest rain-water, until it ceases to give out colour.

Brazil-wood Lake.—1. Take of ground Brazil wood 1 lb., water 4 gallons; digest for 24 hours, then boil for 30 or 40 minutes, and add of alum 1½ lb., dissolved in a little water; mix, decant, strain, and add of solution of tin ½ lb.; again mix well and filter; to the clear liquid add, cautiously, a solution of salt of tartar or carbonate of soda, as long as a deep-coloured precipitate forms, carefully avoiding excess. 2. Add washed and recently precipitated alumina to a strong and filtered decoction of Brazil wood. Inferior to the last.

Cochineal Lake.—1. Cochineal (in coarse powder) 1 oz.; water and rectified spirit, of each, 2½ ozs.; digest for a week; filter and precipitate the tincture with a few drops of solution of tin, added every 2 hours, until the whole of the colouring matter is thrown down; lastly, wash the precipitate in distilled water and dry it; very fine. 2. Digest powdered cochineal in ammonia water for a week, dilute the solution with a little water, and add the liquid to a solution of alum, as long as a precipitate falls, which is the lake. Equal to the last. 3. Coarsely powdered cochineal 1 lb., water 2 gallons; boil 1 hour, decant, strain, add a solution of salt of tartar, 1 lb., and precipitate with a solution of alum. By adding the alum first, and precipitating the lake with the alkali, the colour will be slightly varied. All the above are sold as carminated or Florence lake, to which they are often superior.

Lac Lake.—Boil fresh stick-lac in a solution of carbonate of soda, filter the solution, precipitate with a solution of alum, and proceed as before. A fine red.

Madder Lake.—1. Take of Dutch grappe or crop madder 2 oz., tie it in a cloth, beat it well in a pint of water in a stone mortar, and repeat the process with fresh water (about 5 pints) until it ceases to yield colour; next boil the mixed liquor in an earthen vessel, pour it into a large basin, and add of alum 1 oz., previously dissolved in boiling water, 1 pint; stir well, and while stirring, pour in gradually of a strong solution of carbonate of potassa (salt of tartar) 1½ oz.: let the whole stand until cold, then pour off the supernatant liquor, drain, agitate the residue with boiling water, 1 quart (in separate portions), decant, drain, and dry. Product, ½ oz. The Society of Arts voted their gold medal to the author of the above formula. 2. Add a little solution of acetate of lead to a decoction of madder, to throw down the brown colouring matter, filter, add a solution of tin or alum, precipitate with a solution of carbonate of soda or of potassa, and otherwise proceed as before. 3. Ground madder, 2 lbs.; water, 1 gallon; macerate with agitation for 10 minutes, strain off the water, and press the remainder quite dry; repeat the process a second and a third time; then add to the mixed liquors, alum, ½ lb., dissolved in water, 3 quarts; and heat in a water-bath for 3 or 4 hours, adding water as it evaporates: next filter, first through flannel, and when sufficiently cold, through paper; then add a solution of carbonate of potassa as long as a precipitate falls, which must be washed until the water comes off colourless, and lastly, dry. If the alkali be added in 3 successive doses, 3 different lakes will be obtained, successively diminishing in beauty.

Orange Lake.—Take of the best Spanish annotta 4 ozs.; pearlash, ¾ lb.; water, 1 gallon; boil it for half an hour, strain, precipitate with alum, 1 lb., dissolved in water, 1 gallon, observing not to add the latter solution when it ceases to produce an effervescence or a precipitate. The addition of some solution of tin turns this lake a lemon yellow; acids redden it.

Yellow Lake.—1. Boil French berries, quercitron bark, or turmeric, 1 lb., and salt of tartar, 1 oz., in water, 1 gallon, until reduced to one half; then strain the decoction and precipitate with a solution of alum. 2. Boil 1 lb. of the dye-stuff with alum, ½ lb.; water, 1 gallon, as before, and precipitate the decoction with a solution of carbonate of potash.

Artificial Ultramarine.—This is obtained by several processes, of which the following are examples:—1. Take kaolin, 37 parts; sulphate of soda, 15; carbonate of soda, 22; sulphur, 18; and charcoal, 8 parts; mix these intimately, and heat in large covered crucibles for twenty-four to thirty hours. The resulting product is then to be again heated in cast-iron boxes at a moderate temperature, until the required tint is obtained; it is finally pulverised, washed in a large quantity of water, and the floating particles allowed to subside in a separate vessel; the deposited colour is now collected and dried. 2. Expose to a low red heat, in a covered crucible as long as fumes are given off, a mixture composed of: kaolin, 2 parts; anhydrous carbonate of soda and sulphur, of each 3 parts. Some persons use one-third less carbonate of soda.

Twaddell's Hydrometer, which is much employed for ascertaining the strength of soda and chloride of lime solutions, etc., is so graduated and weighted that the 0 or zero mark is equal to 1,000, or the specific gravity of distilled water at the temperature of 60° F., and each degree on the scale is equal to ·005; so that by multiplying this number by the number of degrees marked on the scale, and adding 1·, the real specific gravity is obtained. Thus 10° Twaddell indicates a specific gravity of 1050, or 1·05, and so on.

Imitation Manilla Pulp from Wood.—Mr. George E. Marshall, of Turner's Falls, Mass., patented a process some years back by which wood, under the action of hot water, and under a heavy pressure, acquires the characteristic colour of manilla. The wood, having been cut as usual, is placed in a closed vessel or tank capable of resisting high pressure, if necessary, of 450 lbs. to the square inch, the material being closely packed. At the bottom of this tank is an opening with a valve, through which the water, previously heated to a point above boiling, and below 280°, is forced by a hydraulic press to such an extent as to saturate and to completely permeate the wood, and to soften and drive out of the pores the gum, resins, and acids; and if the temperature is kept sufficiently hot, it gives the pulp the desired colour belonging to a finely-made manilla paper. This may be aided somewhat by the introduction of a small quantity of some alkaline substance to act on the acids. The water may be heated in a coil outside, and forced into the tank by a hydraulic press. The water thus heated and forced in leaves the wood or the pulp in the most desirable condition for work and for colour. Pulp made from wood treated below the boiling point will be white; but this process is said to secure the desired manilla colour by raising the temperature to 240° or 250° for a light pulp, and as high as 280° for a dark pulp. No pressure is required from the steam above three atmospheres, but the press may give from 450 to 500 lbs. to the square inch, and practice has shown that the greater the pressure the more speedy is the operation on the wood.*

Testing Ultramarines.—The sample of ultramarine should be examined as to its power of resisting the action of alum solutions, which may readily be done by the method suggested by Mr. Dunbar :—" Dissolve the same amount of each sample in water, and mix in this water about ½ lb. of pulp. When thoroughly mixed, and each lot of pulp is well and evenly coloured, add one glassful

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* New York *Paper Trade Journal*, 1878.

III.—TABLE SHOWING THE SPECIFIC GRAVITY CORRESPONDING WITH THE DEGREES OF BAUMÉ'S HYDROMETER.

Liquids denser than Water.

Degrees.	Specific Gravity.	Degrees.	Specific Gravity.	Degrees.	Specific Gravity.
0	1·0000	26	1·2063	52	1·5200
1	1·0066	27	1·2160	53	1·5353
2	1·0133	28	1·2258	54	1·5510
3	1·0201	29	1·2358	55	1·5671
4	1·0270	30	1·2459	56	1·5833
5	1·0340	31	1·2562	57	1·6000
6	1·0411	32	1·2667	58	1·6170
7	1·0483	33	1·2773	59	1·6344
8	1·0556	34	1·2881	60	1·6522
9	1·0630	35	1·2992	61	1·6705
10	1·0704	36	1·3103	62	1·6889
11	1·0780	37	1·3217	63	1·7079
12	1·0857	38	1·3333	64	1·7273
13	1·0935	39	1·3451	65	1·7471
14	1·1014	40	1·3571	66	1·7674
15	1·1095	41	1·3694	67	1·7882
16	1·1176	42	1·3818	68	1·8095
17	1·1259	43	1·3945	69	1·8313
18	1·1343	44	1·4074	70	1·8537
19	1·1428	45	1·4206	71	1·8765
20	1·1515	46	1·4339	72	1·9000
21	1·1603	47	1·4476	73	1·9241
22	1·1692	48	1·4615	74	1·9487
23	1·1783	49	1·4758	75	1·9740
24	1·1875	50	1·4902	76	2·0000
25	1·1968	51	1·4951		

IV.—TABLE OF BOILING POINTS OF ALKALINE LEYS.

Alkaline Ley.	Specific Gravity.	Percentage of Alkali.	Boils at degrees Fahrenheit.
Soda	1·18	13	217°
Potash....	1·23	19·5	220
Soda	1·23	16	220
Potash....	1·28	23·4	224
Soda	1·29	19	224
Soda	1·32	23	228
Potash....	1·33	26·3	229
Soda	1·36	26	235
Soda	1·40	29	242
Potash....	1·42	34·4	246
Soda	1·47	34	255
Potash....	1·44	36·8	255
Soda	1·5	36·8	265
Potash....	1·52	42·9	276
Potash....	1·6	46·7	290
Soda	1·63	46·6	300
Potash....	1·68	51·2	329

V.—TABLE SHOWING THE QUANTITY OF CAUSTIC SODA IN LEYS OF DIFFERENT DENSITIES (WATER 1,000).

Specific gravity.	Soda per cent.	Specific gravity.	Soda per cent.
1·00	0·00	1·22	20·66
1·02	2·07	1·24	22·58
1·04	4·02	1·26	24·47
1·06	5·89	1·28	26·33
1·08	7·69	1·30	28·16
1·10	9·43	1·32	29·96
1·12	11·10	1·34	31·67
1·14	12·81	1·35	32·40
1·16	14·73	1·36	33·08
1·18	16·73	1·38	34·41
1·20	18·71		

VI.—Table showing the Quantity of Bleaching Liquid at 6° Twaddell (Specific Gravity 1·030) required to be added to Weaker Liquor to raise it to the given Strengths.

Strength of Sample in $\frac{1}{12}$°.	Required Strength.	Proportions Required.	
		Given Sample.	Liquor at 6°.
		parts.	part.
Water	$\frac{8}{12}$°	8	1
1	,,	9¼	1
2	,,	11	1
3	,,	13½	1
4	,,	17	1
5	,,	23	1
6	,,	35	1
7	,,	71	1
Water	$\frac{6}{12}$°	11	1
1	,,	13½	1
2	,,	17	1
3	,,	23	1
4	,,	35	1
5	,,	71	1
Water	$\frac{4}{12}$°	17	1
1	,,	23	1
2	,,	35	1
3	,,	71	1
Water	$\frac{3}{12}$°	23	1
1	,,	35	1
2	,,	71	1

VII.—Comparative French and English Thermometer Scales.

French or Centigrade.		English or Fahrenheit.
0 Cent. or C.	equals	32 Fahr. or F.
5 ,,	,,	41 ,,
10 ,,	,,	50 ,,
15 ,,	,,	59 ,,
20 ,,	,,	68 ,,
25 ,,	,,	77 ,,
30 ,,	,,	86 ,,
35 ,,	,,	95 ,,
40 ,,	,,	104 ,,
45 ,,	,,	113 ,,
50 ,,	,,	122 ,,
55 ,,	,,	131 ,,

COMPARATIVE FRENCH AND ENGLISH THERMOMETER SCALES—*continued.*

French or Centigrade.				English or Fahrenheit.		
60	Cent. or C.		equals	140	Fahr. or F.	
65	,,		,,	149	,,	
70	,,		,,	158	,,	
75	,,		,,	167	,,	
80	,,		,,	176	,,	
85	,,		,,	185	,,	
90	,,		,,	194	,,	
95	,,		,,	203	,,	
100	,,	(Water boils)	,,	212	,,	(Water boils)
200	,,		,,	392	,,	
300	,,		,,	572	,,	
356	,,	(Mercury boils)	,,	662	,,	(Mercury boils)

VIII.—WEIGHTS AND MEASURES OF THE METRICAL SYSTEM.

(From the British Pharmacopœia.)

WEIGHTS.

1 Milligramme = the thousandth part of one gramme, or 0·001 gramme.
1 Centigramme = the hundredth ,, ,, 0·01 ,,
1 Décigramme = the tenth ,, ,, 0·1 ,,
1 Gramme = weight of a cubic centimètre of water at 4° C. 1·0 ,,
1 Décagramme = ten grammes . . . . . 10·0 ,,
1 Hectogramme = one hundred grammes . . 100·0 ,,
1 Kilogramme = one thousand grammes . . . 1,000·0 ,,

MEASURES OF CAPACITY.

1 Millilitre = 1 cubic centimètre, or the measure of 1 gramme of water.
1 Centilitre = 10 ,, ,, 10 ,,
1 Décilitre = 100 ,, ,, 100 ,,
1 Litre = 1,000 ,, ,, 1,000 ,,

MEASURES OF LENGTH.

1 Millimètre = the thousandth part of one mètre, or 0·001 mètre.
1 Centimètre = the hundredth ,, ,, 0·01 ,,
1 Décimètre = the tenth ,, ,, 0·1 ,,
1 Mètre = the ten-millionth part of a quarter of the meridian of the earth.

IX.—TABLE OF FRENCH WEIGHTS AND MEASURES.

Kilogramme, 1,000 grammes, equals 2 lbs. 3¾ ozs. nearly.
Gramme (the unit) equals 15·432 grains.

FRENCH MEASURE OF VOLUME.

1 Litre (the unit) equals 34 fluid ozs. nearly.

LONG MEASURE.

Mètre (the unit)	equals	39·371	inches.
Décimètre (10th of a mètre)	,,	3·9371	,,
Centimètre (100th of a mètre)	,,	0·3937	,,
Millimètre (1,000th of a mètre)	,,	0·0393	,,

LIST OF WORKS RELATING TO PAPER MANUFACTURE.

"Practical Remarks on Modern Paper." J. Murray. Edinburgh, 1829.

"Manuel du Fabricant des Papiers." L. S. Le Normand. Paris, 1834.

"L'Industrie de la Papetrie." G. Planche. Paris, 1853.

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